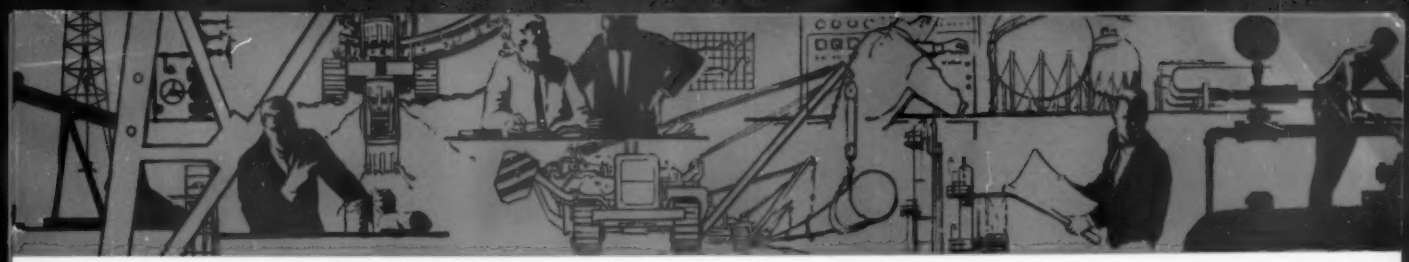

Petroleum Management

A PETROLEUM ENGINEER PUBLICATION August, 1961

Perils of Petroleum

A Fresh Look at Motivation

Operations of 75 Companies

Lease Tank Mixing Pays Off

Esso Refines Automatic Welding

How to Evaluate Mud Desanding

Heat Transfer's Growing Potential

"Chloe" Pipeline Laid in Louisiana

Recent Nucleate Boiling Development

LOOK AT THE TURBULENCE in casing or tubing during a well stimulation treatment. Until recently, much of the available pumping horsepower was spent just to overcome this turbulence.

TURBULENCE IS SUPPRESSED when Slick Water or Slick Oil is added to the treating fluid. Injection rates may be more than doubled or required horsepower may be cut by as much as 70 per cent.

how Dowell's new friction-reducing agents help increase profits from fracturing and acidizing

These cross-section illustrations, as visualized by an engineer, show fluid flow down casing or tubing during fracturing or acidizing. They show how extreme turbulence wastes pump horsepower; much of the available horsepower must be used to fight this turbulence.

Slick Water* and Slick Oil* – the Dowell-developed friction-reducing agents for water, acid and oil – have made it possible to more than double the injection rate with the same horsepower. In other cases, a given injection rate has been achieved with only one pump instead of three. In still other cases, these agents have saved the cost of pulling tubing. High-injection-rate treatments have been performed down strings of 2⅞-inch casing in multiple tubingless completions. Slick Water and Slick Oil have made large fracturing treatments economical for some marginal wells by permitting the use of lower-cost fluids. They have helped many operators get exceptional production increases per dollar invested.

Ask your Dowell representative how these new friction-reducing agents can help you increase profits from well stimulation. Dowell services and products are offered from more than 150 offices and stations in the United States, Canada, Venezuela, Argentina, Germany, France and the Sahara area. Dowell, Tulsa 1, Oklahoma.

*DOWELL TRADEMARK

SERVICES FOR THE OIL INDUSTRY **DOWELL** DIVISION OF THE DOW CHEMICAL COMPANY

An Exciting Improvement

With this issue of PETROLEUM MANAGEMENT, the editors bring you a handsomely improved magazine. From the exciting new cover, through all the beautifully redesigned pages, you will find the results of many months of research and planning. Our one aim was to bring you one of the best looking, most easily read industrial publications in the nation.

Always a great magazine in its sound, authoritative information, PETROLEUM MANAGEMENT adds a new beauty to its page design and greater ease in reading to make it more valuable than ever to its readers.

And we're not through growing yet! During the coming months we have many informative new feature articles coming up that are being written to keep you the best informed magazine reader in the petroleum industry.

Joe B. Hooks

PUBLISHER

News

WHO'LL ADVISE USA?

What U. S. agency will advise on military supplies of oil products in case of emergency? The Military Petroleum Advisory Board was disbanded in 1956. National Petroleum Council supplies depth studies but isn't set up at present for day-to-day reports. Even preparation for an emergency could see exceptional needs. Those jet bombers use a tank car load of fuel in two hours.

GAS PRICES SET HIGHER

An FPC examiner authorized Shell to sell 701 billion cu ft of gas at 20½¢/Mcf from Oklahoma's Elk City field to Panhandle Eastern Pipe Line Company. This was 5½¢ above area-pricing. Not long after another examiner approved sale of 238 billion cu ft from Northwest Oklahoma at 17¢/Mcf to Michigan Wisconsin Pipe Line Company. This is 2¢ above FPC staff's recommendation.

OPERATOR WANTED

The Navy is looking for a new operator of the 46,095-acre, 1-billion-bbl-plus-reserve Elk Hills Petroleum Reserve in California. Bids for the job will be opened August 16th. Standard Oil of California owns a checker-boarded 8541-acres and gets 10% of the 11,000 bbl daily production. Standard has been operator since 1942, but says it will get out as of next January because operations have been uneconomical. New operator must be okayed by President, Department of Justice and armed services committees of Congress.

LIBERIA GETS REFINERY

Hunt International (foreign operating unit of N. B. Hunt, Dallas, Texas) has reached agreement with Liberia officials to build a refinery in the West African country. Capacity is expected to be 15,000 b/d, more than enough to supply Liberia's demand (1200 b/d). Under an exclusive 25-year concession, net profits will be split 50-50.

NEW MARKETERS IN U.K.

Continental Oil enlarged its marketing outlets in Europe by acquiring 400 service stations in Northern England. The outlets are part of property purchased from Jet Petroleum. Last year Conoco bought the Sopi stations in Germany. England has been invaded by eager marketers. ENI (Italy) and TOTAL (CFP, France) have entered the field. The latter is building a new terminal on the Manchester Ship Canal.

STEEL UNION SIGNS

United Steelworkers approved a new four-year contract with Lone Star Steel. Employees at the big East Texas plant had been working without a contract since September of 1959. Howard Jensen, vice president, said, "The new contract is virtually the same as that proposed two years ago by the company." Pay rates were not in dispute; management rights were.

From the Desk of

ABBOTT SPARKS

Advertising Director

The Magazine you're holding
is the new look in The Engineer . . .
from cover to cover.

As you leaf through the issue, you may become aware
of some changes that are dramatic . . . others quite subtle.

Why the face lifting?

Reading habits change, as do styles. As long as we hope to
compete for the reader's attention, we'll have to give him
what he's looking for.

Most of the credit for this job goes to Dr. Arthur Gould,
prominent editorial consultant. His client magazines have
won every major award for editorial excellence offered
in the business press.

Closer attention from our readers obviously means better
readership of editorial and advertising pages. Our
objective is to produce the most attractive oil and gas
magazines available.

Look it over carefully. After you pass judgment, and if
time permits . . . give us your verdict. We'll appreciate
it.

News

ACQUISITIONS HIT SNAG

Internal Revenue Service has thrown a spanner into acquisition of oil property. Usually an advance ruling is given by IRS on a proposed transaction to tell whether it will qualify for capital gains or the profit must be taxed as ordinary income. This is causing a delay in the purchase of Honolulu Oil for $380 million by Pan American, Tidewater and 10 other companies. Socony Mobil's acquisition of Republic Natural Gas for $150 million may also be held up by the IRS decision. Producing Properties Inc. has acquired the properties of Shoreline Petroleum for more than $8 million. Bishop Oil has agreed to sell its Canadian subsidiary to Shell for $5.6 million. Slick Oil will sell its properties to Midhurst Oil for $7.5 million, depending on a favorable tax ruling.

HARRIS BILL ENDORSED

IPAA's Natural Gas committee endorsed the legislative measure proposed by Representative Oren Harris (D-Ark.). The measure would exempt small producers from control and would prohibit a gas company from applying for a rate increase while a previous application was pending before the FPC.

TO TOP FPC SPOT

Joseph C. Swidler will move into the top spot on the FPC, succeeding the present chairman, Jerome Kuykendall, on September 1. Kuykendall will be a member of the commission until his term expires next June, unless he resigns to enter private business, as he has indicated he might. The announcement was made when Swidler and Howard Morgan were sworn in as new members of FPC. Robert M. Weston, FPC examiner, is supported by important leaders to fill the vacancy caused by Frederick Stueck's sudden death.

"WAR" BOWS TO BUSINESS

Kuwait began independence with political hassles—Iraq claimed it and British troops were moved to the frontier. USSR spent its 95th veto to keep it out of UN and Arab neighbors speculate on how to spread the Kuwait oil wealth. In business the little black gold mine went ahead with formation of the Kuwait Petrochemical Company held principally by the government and Oronzio de Nora, Italian chemical construction firm. It will spend $45 million on a complex that will use natural gas as feedstock.

FOREIGN AID: $5.1 BIL.

U. S. paid $5.1 billion in 1960 in grants, credits and other assistance abroad, the Department of Commerce announced. Of the $3.3 non-military aid, India led with $521 million; Korea was next; then Pakistan with $228 million net assistance. These figures include transfer of farm products for foreign currency, which amounted to $1.2 billion.

Petroleum Management

August, 1961—No. 9, Vol. 33

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THE BEST SAFEGUARD IS KNOWLEDGE

In the oil and gas industry, knowledge is acquired only through long years of experience. Republic, as a pioneer oil bank in the South . . . with the South's largest Oil and Gas Department, has this knowledge. For decades, Republic has been pacing the industry, keeping thoroughly informed on new trends and developments, credit ratings, equipment distributors and all the varied factors involved in oil and gas financing.

Republic offers you not only unlimited resources but also the strength which comes from specialized knowledge. Next time you need bank service on an oil or gas matter, talk to Republic, indisputably a leader in the field. We understand your problems . . . speak your language and have the resources to best protect your interests.

REPUBLIC NATIONAL BANK
OF DALLAS

"My Bank" to the Oil and Gas Man

CAPITAL AND SURPLUS $105,000,000 ★ LARGEST IN THE SOUTH ★ MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

Course of Oil

It Could Be Worse!

When Donald Frendzel reported on Soviet oil for the Department of Interior he concluded there were some positive aspects of increased USSR oil output and exports; that availability of Soviet oil will (1) increase economic competition in oil sales and (2) allow some consumers to become less dependent on Middle Eastern oil.

There isn't much doubt about the Soviet's concern with oil. In July 1960 a Moscow journal stated: "It should be borne in mind that oil concessions represent the foundation of the entire edifice of Western political influence in the (less developed) world, of all military bases and aggressive blocs. If this foundation cracks, the entire edifice may begin to totter and then come tumbling down."

Oil energy is the foundation of political confidence. Its power is used politically by the U.S. as well as by the Soviet. We've used it to good effect in every national crisis. We are using it now as an anchor for our allies.

According to Emile Bustani, Lebanon business leader, "It is said that the United States' threat to cut off the provision of American oil to Britain and to France was among the principal factors which compelled the two belligerents to agree to a ceasefire . . ."

This was the Suez Canal crisis; later oil products flowed to Western Europe from the U. S. and kept factories open and men working.

Few nations are so naive as to believe the Soviet would be a more dependable supply than the Middle East. The buyers, with tongue in cheek, take the bargain oil that Socony President Nickerson said Russia sells for a $1.89/bbl average to the West and for $3.02/bbl to Reds.

As for the next point — increase in economic competition — this is really costing us. What about need for U.S. funds to shore up Venezuela's economy? Part can be credited to Soviet cut-throat competition. Iran needs U.S. funds, largely because crude oil prices were lowered to come closer to Soviet offers.

So we would not agree with Mr. Frendzel's bright view but we can cheerfully say, it could be worse.

One aspect that's almost pleasing is the virtual certainty that the Russians are in part donating their energy resources to the noncommunist world. U. S. oil men who visited there reported, "The first impression of Russian producing operations is that cost is no item." Cost seems likely to be more than price. Some Communist economist is going to figure this out some day — perhaps soon.

Another point: The very fact that USSR must sell its oil at cut rates to obtain buyers speaks loudly. Outside of its satellites it appears Russia can't get the same price — in hard currency — that Western oil brings.

Then, whenever we think about the aggressive Soviet government, we are thankful for one thing — that the Red leaders who kidnapped the great expanse and population of the Russias were tied to the most limiting economic system ever devised.

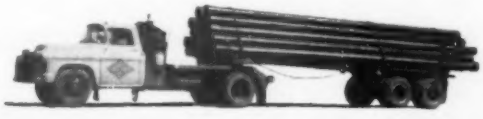
Be glad of one thing — that there aren't 500,000 independents out on the steppes hunting for oil. If the Soviet were a free enterprise, capitalist country, we'd have been drowned in oil already.

— *Ernestine Adams*

Congrats and $25 to Peter Fernandez, Texaco T'Dad Inc.18 Concord Road, Pointe-a-Pierre Trinidad, W.I.

Joe Roughneck is apt to set up a howl, too, if asked to handle steel pipe that is less than superior.

More and more experienced oil and gas men have switched to Lone Star API casing, tubing and line pipe, because it's "tough, top quality and delivered fast." Your best guarantee of rugged API standards is Lone Star's uncompromising quality control.



Neighbor, wherever you are, specify Lone Star and we both get a good deal.

Lone Star STEEL COMPANY

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Profile

J. Ed. Warren, President
Cities Service Company

Men in metal helmets walk the steel girders of a construction job across from Sixty Wall Tower in the financial center of downtown Manhattan. Seeing them from his office on the 17th floor of the Tower, must stir memories in the mind of J. Ed. Warren, president of Cities Service Company. He wore helmets like that back in the days when, as a roustabout and tool dresser, he began his oil career in Wyoming.

When he graduated from University of Washington in 1923 with a BS in geology, he signed up with U. S. Geological Survey. He was primed for adventure in the icy tundra of Alaska, working with a survey team at Port Barrow. Then, as he was waiting for embarkation, word came that the team must be reduced to 18 members. As the last to be signed, Warren was left on shore and he wound up in Wyoming, shovel in hand, working for Carter Oil Company.

By working 84 hours a week, Warren, to use his own words, "accumulated enough money to pay off my college debts, marry my college sweetheart, Marjorie Fisken, and make a down payment on a car."

The automobile was the only bit of luxury. The cabin they occupied had neither electricity nor running water. They did have gas, but not always. One night, when there was no gas, the temperature fell to 24 degrees below zero, and the Warrens kept thawed out by piling rugs on the bed and warming their hands with candles.

Accepting the Texas Mid-Continent Oil and Gas Association Distinguished Service Award in 1955, Warren observed "the one who deserves this is Mrs. Warren." He then went on to tell how, in the first three years of married life, Mrs. Warren set up living quarters in five states while he worked as petroleum engineer for the U. S. Bureau of Mines in Denver, Colorado; as a geological scout in New Mexico, and as production superintendent in the Texas Panhandle for Marland Oil Company and its successor, Continental Oil Company.

In 1934 Warren resigned as assistant to the Continental president to become associated with Carl B. King Company of Midland, Texas. Nine years later he became its president. Meanwhile, serving also as managing partner of King, Warren and Dye, independent oil producers, he became one of the best known men in the industry with the result that he was called to Washington to serve as Deputy Administrator of the Petroleum Administration for Defense in 1952 and 1953.

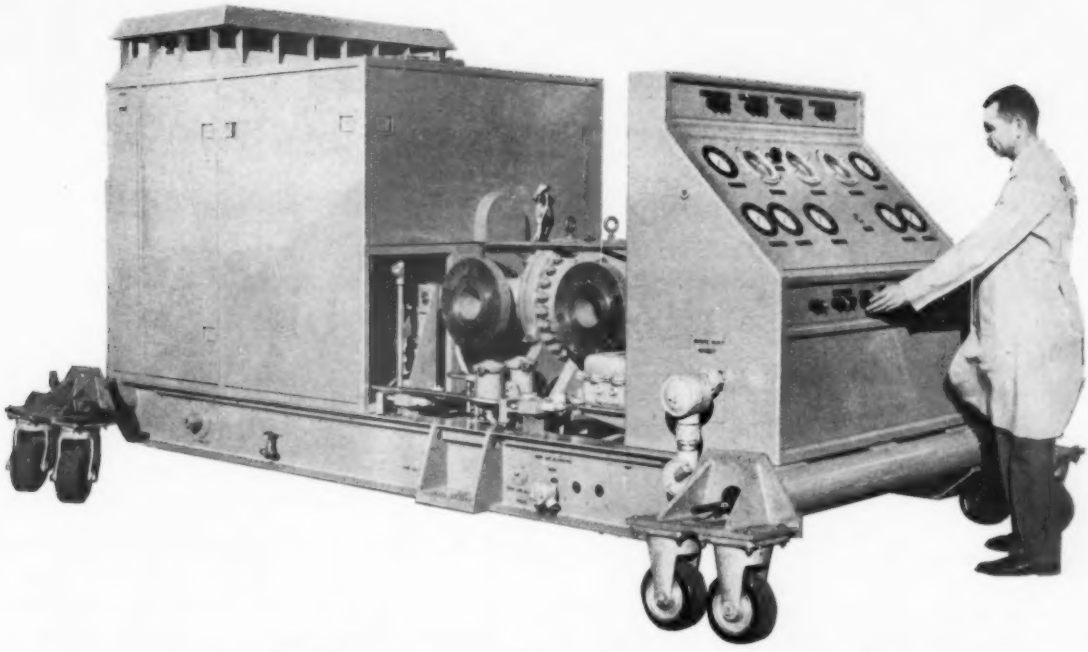
In December, 1953, Warren was named vice president of First National City Bank of New York to head its Petroleum Department. This led to the senior vice president post with worldwide responsibilities.

He was called back in 1954 to serve as a member of a four-man task force for the President's Committee on Energy Supply. During the Suez crisis he became consultant to Secretary of Interior Fred Seaton and to Director of Defense Mobilization Arthur S. Fleming.

With little time for leisure his duties did afford him one special pleasure. Because Texas was an industry center, his trips there allowed him to visit his son, Jack, and three grandchildren, in Tyler, and his daughter, Mrs. Sidney Purser, in Austin.

In 1958 he went with Cities Service Company, as chairman of the executive committee and a member of the board. The next year he was elected president. J. Ed. Warren has a major responsibility for the future well-being of a fully-integrated organization, with more than 17,000 employees. Operations extend throughout the United States, and into Canada, Central and South America, Europe, and Africa. It is rated among the first dozen oil companies of the nation and among the first half-dozen in natural gas.

It's a far trek from frontier cabin and warming your hands with candles to the presidency of a billion-dollar enterprise but in America — as J. Ed. Warren has proved — it is still possible to make the journey. ■



Compact Solar gas turbine compressors cost less to buy, run and maintain

Solar centrifugal gas turbine compressors are so light and compact they can be mounted on the back of a truck, skids or extremely lightweight foundations. Their simplified design and construction mean they cost less to buy, install, operate and maintain. Their versatility makes them ideal for both field boosting and main pipeline applications.

Solar compressors are now in operation powered by Solar's *Saturn* 1100 hp industrial gas turbine. The *Saturn* engine weighs just 1200 lbs and measures 77 inches in length by 44 inches in width by 44 inches in height. It is virtually vibrationless, starts instantly and requires no warmup—making it ideal for remote or unattended operation.

Solar compressors represent a fundamental advance in the field, made possible by high performance, long-life Solar turbines. Driving the compressor directly at turbine rotating speeds results in a small, high efficiency package for the range of 5 to 150 MM SCFD or 75 to 1500 cfm.

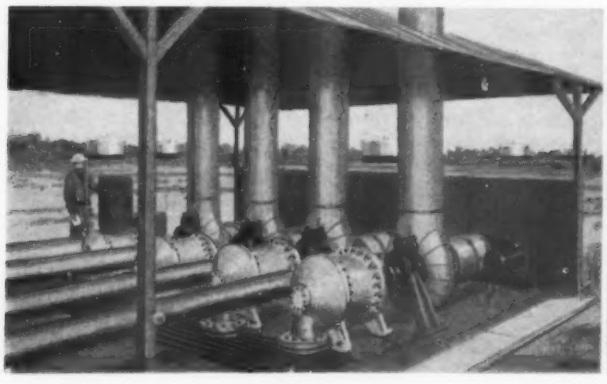
A new concept of multi-staging and interchangeable compressor wheels allows low cost field changes to accommodate new flow and pressure requirements. Maintenance is unusually simple and is facilitated by the compressor's easy portability.

Detailed information on Solar's new gas turbine compressors is available by writing to Dept. J-122, Solar Aircraft Company, San Diego 12, California.

SOLAR

A subsidiary of International Harvester Company

Multiple unit installations facilitate maintenance.



Easy transportation for installation or maintenance.

Conference Table

You Have to Be a Businessman First

For a long time, the petroleum industry has been stressing science and technology. But we need to lean more on economics and business leadership.

That was the theme of a speech by L. F. McCollum, president of Continental Oil Company, at the American Association of Petroleum Landmen. Although he spoke to landmen, his remarks cover every profession and trade in the petroleum industry. "We must continue to sharpen our talents as specialists," he said, "and at the same time, restore our talents as businessmen."

An income tax form is like a laundry list — either way you lose your shirt. — FRED ALLEN

Helping American Way

Mobil Oil Company won a George Washington Honor Medal from the Freedoms Foundation Award at Valley Forge for advertisements in Augusta, Kansas, and East St. Louis, Illinois. The three winning ads are part of a community relations program conducted by Mobil's refineries in the two cities.

Wages and Fringes

The new wage and hour law which goes into effect next Labor Day will cost businessmen $536 million the first year in direct wage increases, according to the Bureau of National Affairs, a Washington report service. This does not consider indirect costs, that is, increasing pay of other workers to maintain the spread between low and high-pay workers nor fringe benefits — that invisible payment that has grown into a load that business feels but employees have a hard time bringing into focus.

Fringe benefits cost an estimated $39½ billion in 1960. In 1947, it was only $10½ billion. Highest fringe benefits are paid in the petroleum industry.

Isn't it about time for both management and employees to look at this factor with the runaway growth. It is supposed to benefit the company and its people but is it really worth the cost? In many ways the employee would be better off having those fringe benefits in his own salary or wage check. He should be the one to decide what he wants to do with the money he earns, not the company.

Fringe benefits are a favorite labor union proposal. You might say that union leaders have forced companies into a paternalism greater than the paternalism they once fought.

This is certainly an area that has not had a full discussion and a package that will be as much this year as our entire defense budget needs looking into. Some $42 billion for fringes is getting out of hand.

Here's the Way You Do It

L. D. "Red" Webster, vice president of public relations and advertising, has made up a check list of how his company, Lone Star Steel, handles its public relations program. This year Lone Star received the Silver Anvil of the American Public Relations Association. This is another top award in a whole row of honors for merit in communications.

Here's the check list if you want to see how your company compares with "Red" Webster's successful operation:

Good Wells Make Good News

Recent Acid Treatments that Solved Special Production Problems

August, 1961

Here are four recent treatments that show how Dowell uses job-tailored materials and engineered treatment planning to help operators solve production problems.

- **Alberta, Canada** (Old Oil Well) This well had been producing from the D-3 through perforations between 5980 and 5992 feet. When production dropped to 30 bopd, operator perforated two upper intervals: 5928 to 5940 feet and 5963 to 5976 feet. Original perforations were closed off temporarily with Dowell diverting agent and the new intervals were acidized with 2000 gallons 28 percent Dowell acid containing a wetting agent. Ten ball sealers were injected after each five barrels of acid. Injection rate was 2 - 2½ bpm at 1760 - 2250 psi. Two weeks after treatment production was 68 bopd.

- **Park County, Wyoming** (New Oil Well) This well was completed into the 98-percent-soluble Madison lime at about 5000 feet. Treatment was engineered by Dowell using the Acid Guide*. 10,000 gallons acid-oil-emulsion type Retarded Acid, containing FLA* fluid loss additive, was injected at 8.5 bpm. 70 days after treatment, production had stabilized at 212 bopd and 187 bwpd -- above average for wells in the same field which had been treated with regular acid.

- **Lamar County, Mississippi** (Old Oil Well) Well was producing 35 bopd and 200 bwpd through perforations between 8644 and 8822 feet in the Tuscaloosa sand. Operator wanted to open up more of the section and improve oil production. Dowell treated using acid and diverting agent in stages. Twelve barrels of diverting agent were followed by seven six-barrel stages of acid. Three barrels of diverting agent were injected between each acid stage. Well came back making 102 bopd and 44 bwpd -- a good production increase plus a greatly improved water/oil ratio.

- **Gray County, North Texas** (Old Oil Well) This well was completed open-hole and shot with nitro in 1959. Production from the Dolomite lime, at 2961 to 3120 feet, had declined to three bopd. Well failed to respond to a large frac treatment. After Dowell acidized with 2000 gallons Stabilized Acid, production levelled off at more than 11 bopd. Operator was more than pleased with results.

Let a Dowell engineer help you select a treatment designed to solve your production problems profitably. Dowell services and products are offered in North and South America, Europe, North Africa and Iran. Dowell, Tulsa 14, Oklahoma.

*Dowell Trademark

SERVICES FOR THE OIL & GAS INDUSTRY
DOWELL
DIVISION OF THE DOW CHEMICAL COMPANY

1. Organization of an economic counselling group composed of officers and directors of every bank in the plant area.
2. Presentation of an Economic Workshop for Clergy attended by preachers of all denominations in the plant area.
3. Establishment of a Teachers Extension course, conducted by East Texas State College, each summer at the plant.
4. Organization of retired employees and establishment of a recreation and reading room for them at the plant.
5. A sports program involving intra-mural softball and basketball between departments, plus a Little League summertime school held at the plant park for area youngsters.
6. A regular program of providing area newspapers, radio and television stations with news features, photos and engravings as desired.
7. Regular radio and television programs over area stations.
8. A weekly column, titled "The Way I See It," by President Germany, which is printed in 15 plant area newspapers for the purpose of airing the company's views, plans, opinions and policies.
9. Establishment of a speaker's bureau composed of employees qualified to speak on specific subjects before civic, school, church and trade groups.
10. Preparation and distribution of films suitable for use by schools, clubs, trade associations, etc.

There are no gains without pains.
— BENJAMIN FRANKLIN

Economies of Modern Equipment

"The manufacturing business has failed to put over its story of real economies modern equipment provides," warned Robert Sheridan, president of Nationwide Leasing Company. His speech before an American Management Association meeting was particularly interesting to us because we've just published the annual world-wide petroleum equipment issue and by the time we get through with that we feel pretty up-to-date.

Sheridan made four major criticisms of sales techniques:

1. Equipment manufacturers are not selling their products — they are bidding. Creative salesmanship seems largely to have gone down the drain. Demonstrating the true economies to be achieved with modern equipment is almost entirely neglected.

2. Equipment manufacturers fail to analyze their customers' real production costs. Thus they do not give their salesmen proper preparation before going out on sales calls.

3. Equipment manufacturers have inadequate knowledge of new financing techniques under which their equipment can be acquired without 100% cash.

4. Many managements are inadequately informed about what new equipment exists and what it can do. While this is partly due to poor selling by equipment manufacturers, it also reflects a failure of management to give adequate time to study of new equipment and its effects of costs.

"Today, 68% of all equipment being used in American industry is more than 10 years old," Sheridan said. "At the end of World War II, this figure was 38%. This growing obsolescence gap may well be a greater national danger than the space gap. The average age of our plant is increasing each year. This means that each year our competitive position grows relatively weaker."

American business spends too much time on thinking about this month, this year. It ought to spend more time preparing for 15 to 20 years from now — the next business generation. — RALPH CORDINER

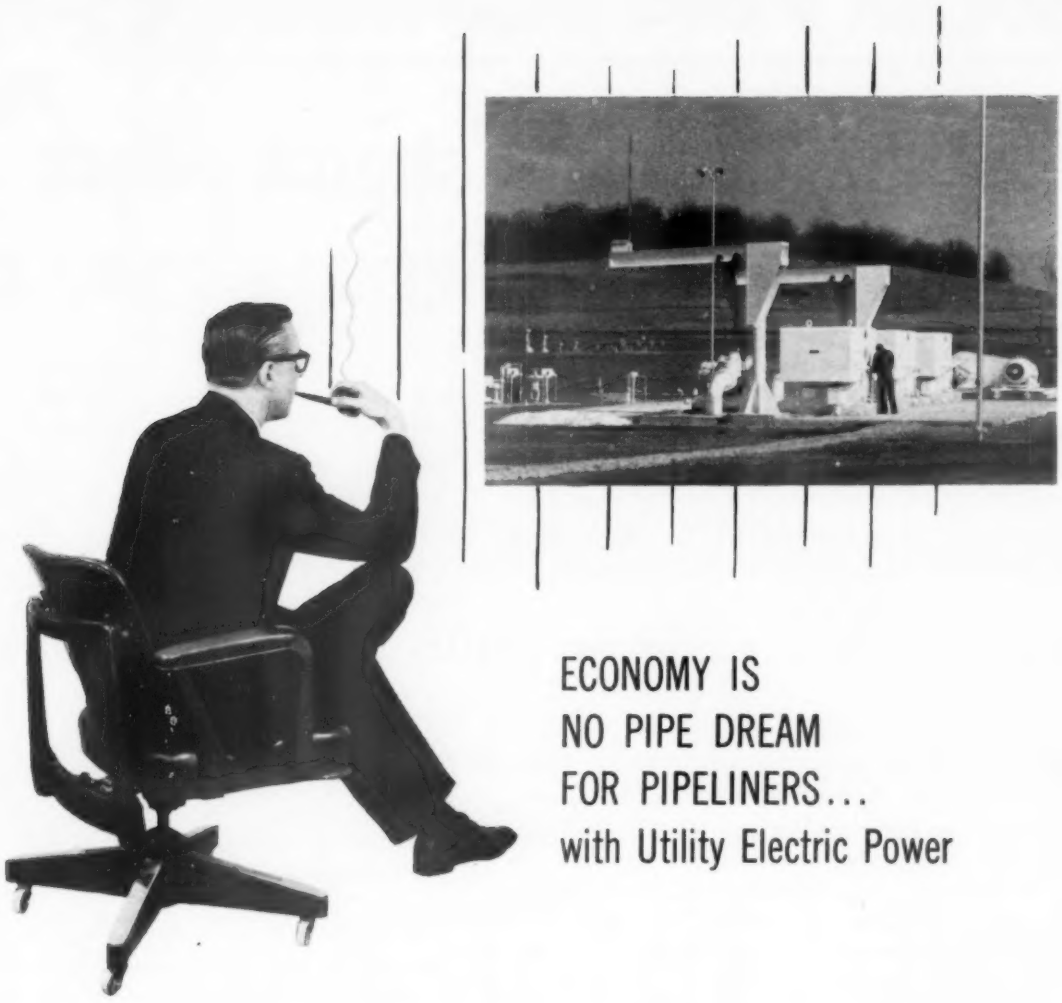
"Labor Productivity" Is Misnomer

Laborers are not paid more because they work harder. In fact they work less. Wages rise because of two things: Investment and technology. We've been saying this for a long time and it's a pleasure to find "Productivity and Wage Settlements", a 50-cent booklet, (U. S. Chamber of Commerce, Washington 6, D. C.) that presents the case so well.

"Productivity" would be small indeed if it were based on labor. How can you say "labor productivity" in the face of restraints put on work by labor organizations and this on top of the physical limitation of labor? You can have increased management productivity, capital productivity, or technological productivity, but you'll have a hard time measuring any notable rise in labor productivity.

One hazard of economics principles is our wandering semantics. Words become propaganda instead of definitive. When you see "labor productivity" you look at labor propaganda.

Memo to Management:



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Here is another pipeline installation utilizing economical utility electric power to move an amazing amount of crude each day. This major company knows the value of efficient electric power and why it gives them more dependable, more economical power service . . . when and where it's needed. Now is the time to analyze your power costs. For the facts on electric power savings consult your Utility Electric Power Company.

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Special report to users of Caterpillar equipment

CAT CATERPILLAR

Parts you can trust
...cost less per hour

New Cat parts stretch dollars "down where the digging's going on"

That's more than just talk! More and more users are conducting their own field trials of ground engaging tools—tips, bits, teeth and edges—to determine which brand gives them the best performance-cost balance. And time after time, they find that genuine Caterpillar ground engaging tools outclass all comers—in production and over-all economy!

Take Cat cutting edges. These edges have been contractor-tested with most of the market's leading brands all over the country. Results: Cat edge wear life—10-60% longer. Cat edge cost—15-50% less per hour. Think of that in terms of dollars!

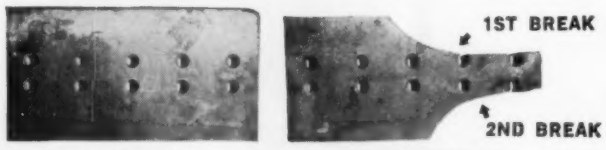
HERE'S A LOOK AT RECENT FIELD TRIALS ON SCRAPER CUTTING EDGES:

Two DW21-470 Scrapers, one with Cat *standard* edges and one with popular brand *thick* edges, were put to work "side-by-side" by a contractor in hard, red clay on an Interstate Highway job. His findings:

Brand	Price	Hours of Life	Cost per Hour
Other	$121.22	1060	$.114
Cat	$128.28*	1360	$.094

HIS SAVINGS WITH CAT EDGES—17.5% PER OPERATING HOUR

*Test completed before recent new low price of $102.30 effective.



CATERPILLAR OTHER BRAND

A Cat 7/8" stinger and another brand *one inch thick* were split in half and a section from each installed on *same* DW21-470 Scraper working in decomposed lava with embedded basaltic boulders. Other brand section broke after 48 operating hours, was reversed but broke again two hours later—a total of 50 hours of life. *Cat edge wear during period was* 1/4", *other brand* 1/2".

Your Caterpillar Dealer has the facts on many of these tests—go over them with him and start to save more now.

Caterpillar continually up-dates its line of ground engaging tools. Some of the newcomers to the line that "stretch your dollars" are: new self-sharpening end bits and ripper tips, patented reversible router bits, and new-design scarifier teeth for Motor Graders. These new money-savers keep production high, costs down.

Caterpillar Tractor Co., General Offices, Peoria, Illinois, U. S. A.

CATERPILLAR

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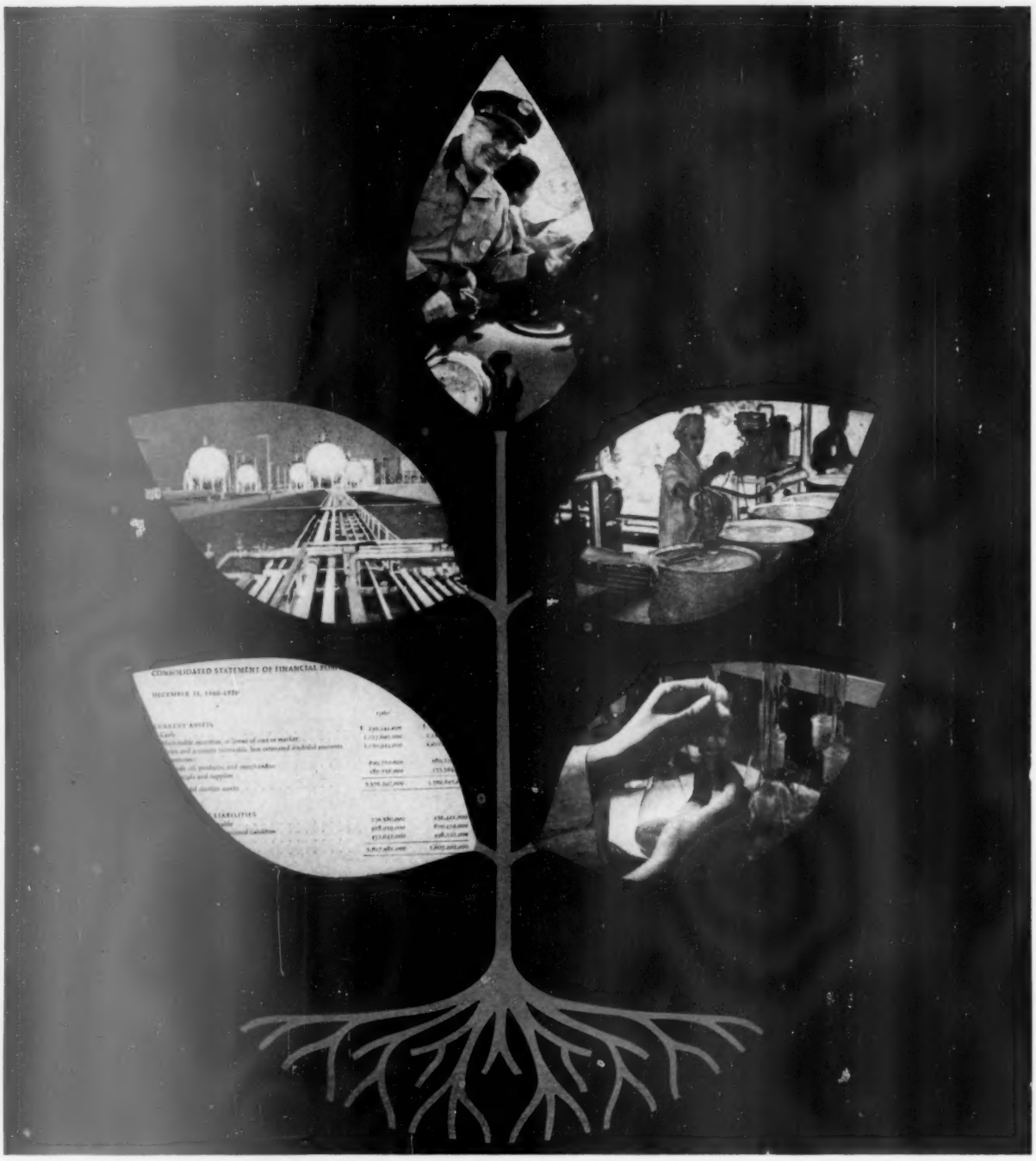

"The oil business is a growth business. The world's need for oil and the things which come from oil is insatiable, and we see no end to a climbing demand. Companies with first-class physical, financial, and human resources, and a dynamic confidence in the future, will share fully and profitably in the great opportunities ahead." *—M. J. Rathbone, President*

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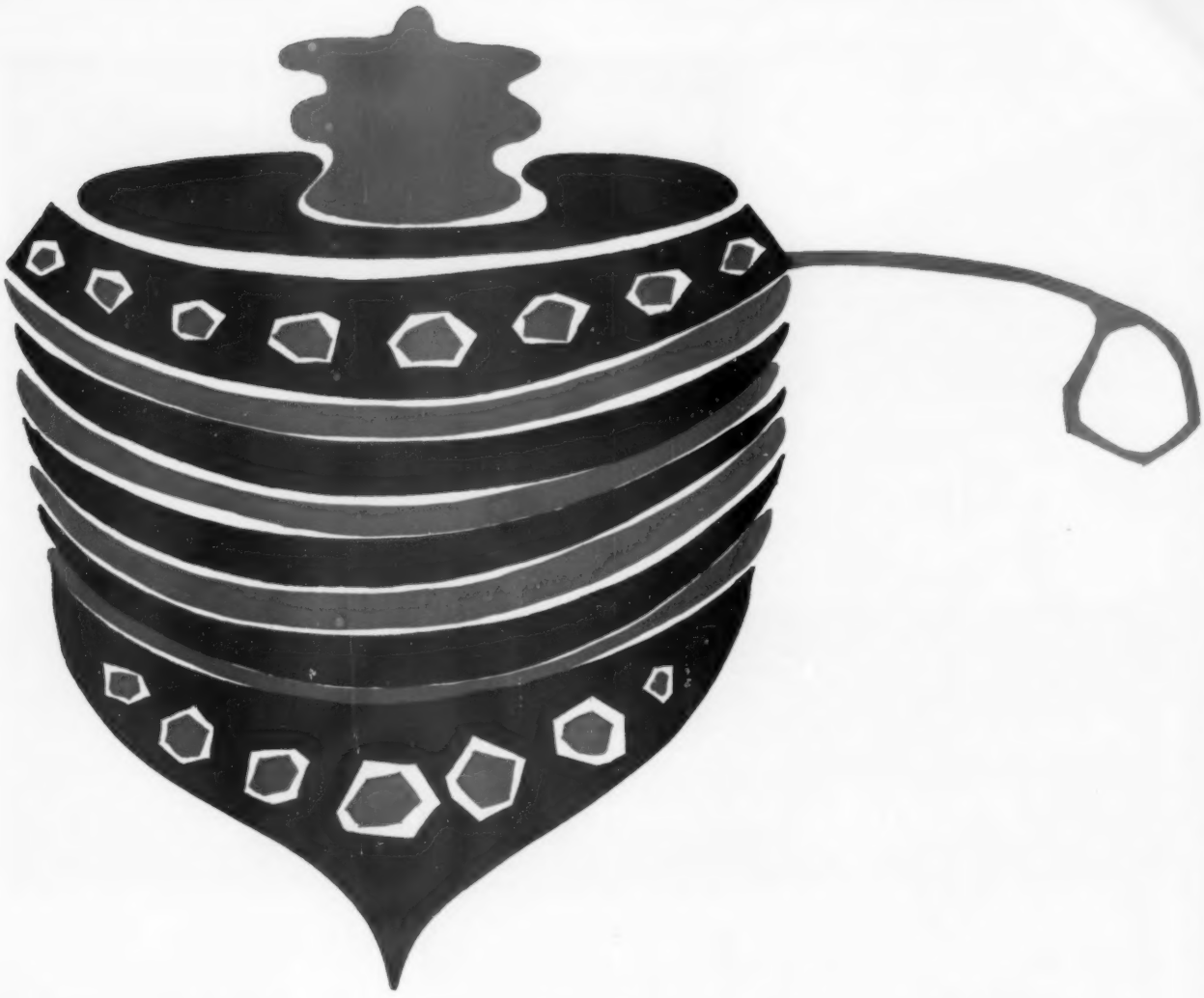

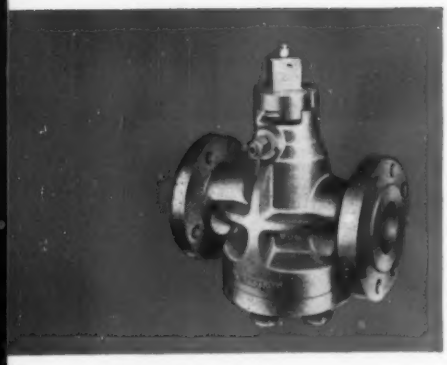

easy to turn: The longest time in the world can be the time it takes to close a valve . . . when you have to close it in a hurry. The sure, easy quarter turn closure of Rockwell-Nordstrom valves saves seconds, even minutes. And you'll save hours of maintenance time on seat replacement with the Rockwell-Nordstrom's sealant system, which replaces the valve's seat from outside. The longer life of these valves—six, eight, even ten times ordinary types—saves days of replacement labor. Add up these times, multiply by the valves in your plant, then again by your labor rate: the result may amaze you. We'll be happy to send you complete information.

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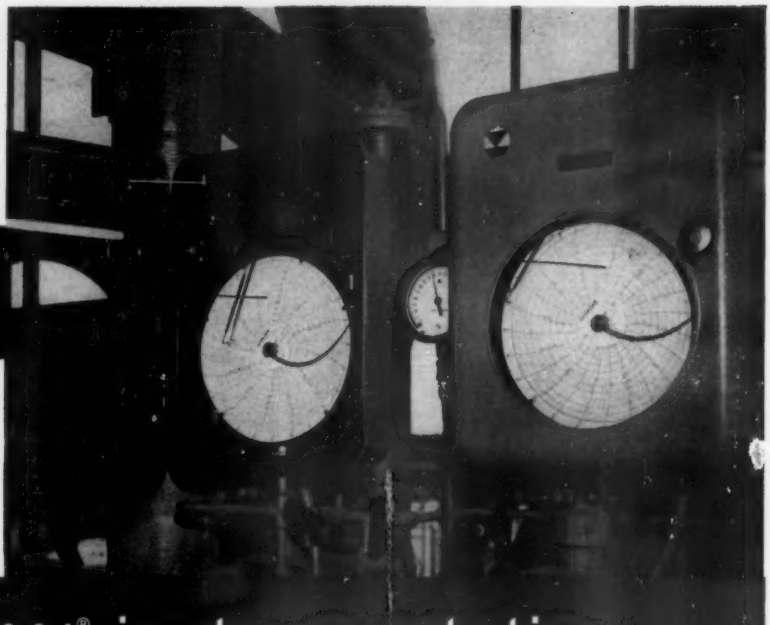

American Integrating Orifice Meters, in a duplex setting, measure gas for boiler at Ft. Lauderdale power plant. These meters are equipped with a fixed gear train to provide a direct reading in cubic feet of gas at base conditions.

AMERICAN® instrumentation solves measurement problem for Florida Power and Light Co.

Florida Power and Light's Ft. Lauderdale power plant. Two of five boilers use 45 million cubic feet of gas per day on an interruptible basis, can consume up to 60 million cubic feet daily.

In each of the eight Florida Power and Light Co. power plants throughout the state, several boilers are fueled by natural gas. Florida Power and Light required a meter that provided a direct reading in actual cubic feet of gas used by each boiler. Measurements would then be transmitted by Telemetering to central data-gathering offices.

American Meter Company supplied a modified Integrating Orifice Meter with a counter reading in cubic feet of gas at standard base conditions that solved their unique measurement problem.

Whether your requirements are simple or complex, you can rely upon American Meter's 125 years of engineering experience to give you the dependable equipment you need for years of accurate, trouble-free measurement and control.

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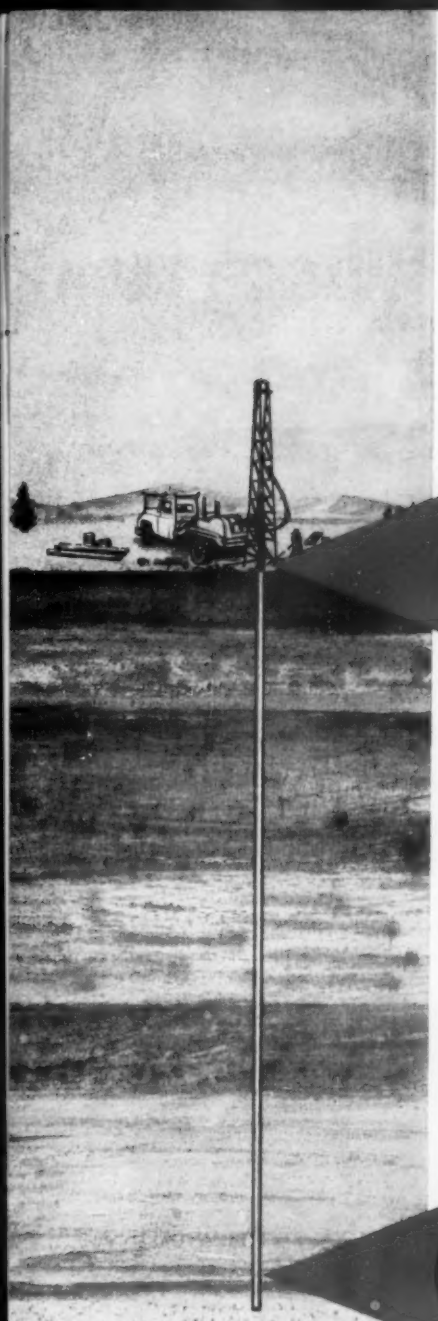

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The Layne Gravel Wall Well is an example of Layne experience, engineering and research. This gravel packing and 134 shutter screen employment affords larger screen openings, reduced friction, reduced draw down and pumping head. It increases specific capacity and makes for more effective retention of native sands. For additional information write for bulletin 900.

From top to bottom, you can depend on Layne for the most complete water service in the industry. This complete service provides undivided responsibility for the delivery of water . . . of the quality and in the quantity required. Over 75 years of *growing* service gives the skill and technical know-how which makes Layne First in the field of water. For additional information write for bulletin 10.

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Layne services do not replace, but coordinate with the services of consulting, plant and city engineers.

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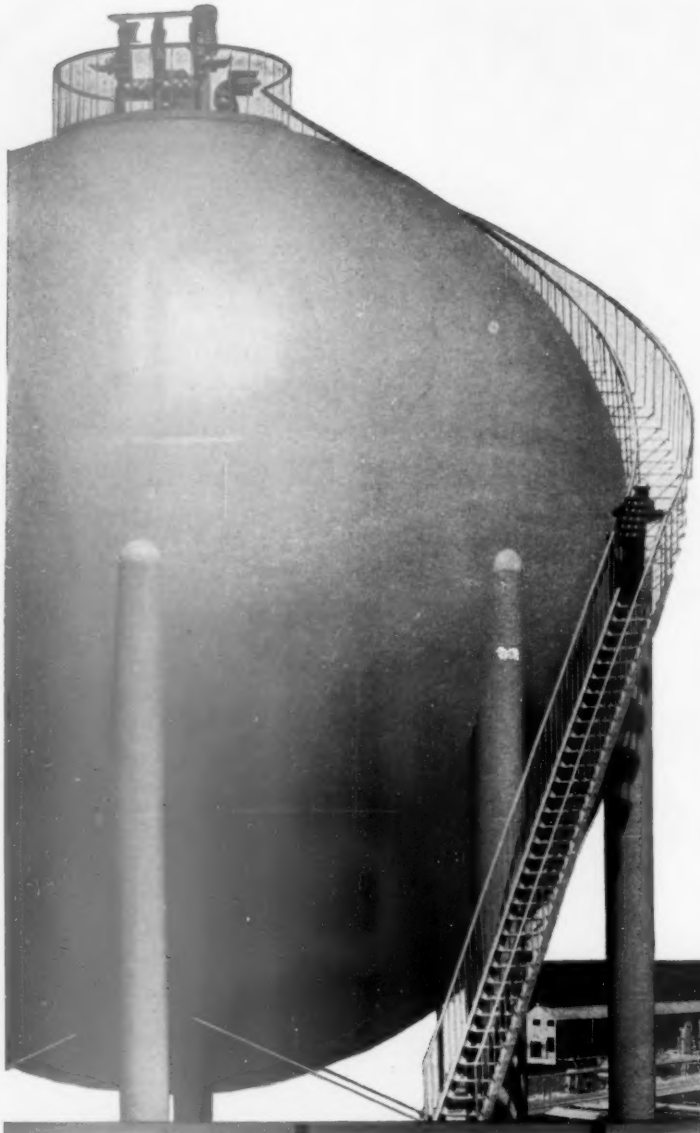

Take those pumps and rigs in the oil fields—or those tanks and pipelines in the refineries! Each needs the tough, colorful, lasting beauty that Rust-Oleum provides. If the surface is rusty, Rust-Oleum 769 Damp-Proof Red Primer can be applied *right over the sound rusted surface* after removing rust scale and loose rust. Special Rust-Oleum Oil Field Finishes match the original equipment colors on pumps and rigs — while other long-lasting Rust-Oleum coatings protect costly tanks and pipe lines.

They're specially made for oil field use — tough, flexible, easy-to-use on the spot by brush or spray! They dry to firm, glossy finishes that resist sun, fumes, heat, moisture, weathering, and blowing dust and sand.

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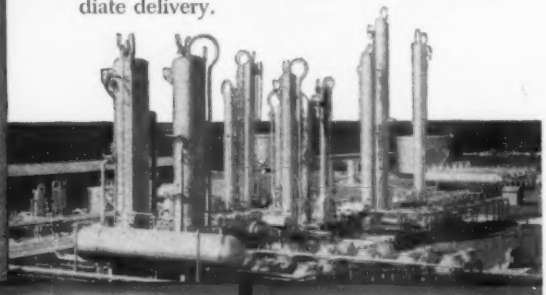

Apply Rust-Oleum 769 Damp-Proof Red Primer directly over sound rusted surfaces.

Follow-up with the Rust-Oleum finish coating in the color of your choice

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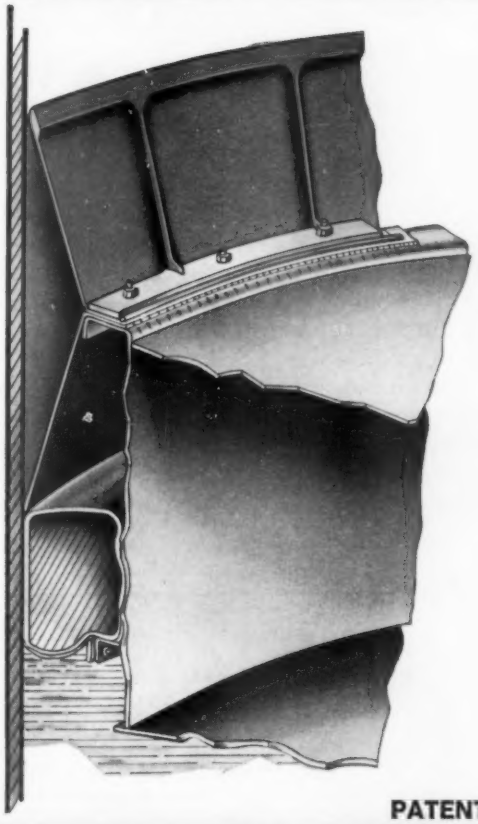

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Tubeseal electro-conductive weather shields are an *exclusive tried and proved development.* They provide positive protection against lightning-caused rim fires. ■ How? By maintaining a *continuous* grounding bond between roof deck and shell—concentration of static charges is impossible. There has *never* been a lightning fire where any of the many hundreds of Tubeseal System Floating Roof Tanks are installed throughout the world—they're "lightning proof." ■ This is scientific and safe storage protection for the entire range of volatile products. Tubeseals can be installed on any of your tanks—new, old, riveted, or welded. You owe it to the future safety of your conservation facilities to investigate. Send for the Tubeseal Bulletin now—it could be important.

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Perils of Petroleum

by Theodore Levitt

The petroleum industry, probably our oldest growth industry, is undergoing a fundamental change. It is not only ceasing to be a growth industry, but may actually be a declining one, relative to other business. I believe that within 25 years the oil industry may find itself in much the same position that the railroads are now in. The petroleum business is a distressing example of how complacency and wrongheadedness can stubbornly convert opportunity into near disaster.

THEODORE LEVITT

Take a deep breath before you read this unflattering picture of the petroleum industry. Dr. Theodore Levitt first presented his views of the oil industry's shortcomings in Harvard Business Review a year ago. Since then, he says, there has been a change on the part of some companies, which emphasize their energy function more thoroughly.

You may not agree with any of Dr. Levitt's appraisal but you'll certainly learn more about what outsiders think of your industry.

Dr. Levitt received his PhD from Ohio State University. He taught, acted as a business consultant in Chicago and is now lecturer on business administration, Harvard University.

Every major industry was once a growth industry. But some now are in the shadow of decline; others have stopped growing. In every case growth is threatened, slowed, or stopped not because the market is saturated, but because there has been a failure of management.

The executives responsible for failure are those who deal with broad aims and policies. The railroads did not stop growing because the need for transportation declined. The railroads are in trouble today because they let others take customers away from them. They assumed themselves to be in the railroad business rather than in the transportation business. They were railroad-oriented instead of transportation-oriented; they were product-oriented instead of customer-oriented.

Industry Obsolescence

In truth, there is no such thing as a "growth industry." There are only companies organized and operated to create and capitalize on growth opportunities. Industries that assume themselves to be riding some automatic growth escalator invariably descend into stagnation. The history of every dead and dying "growth" industry shows a self-deceiving cycle of bountiful expansion and undetected decay. There are four conditions which usually guarantee this cycle:

1. Belief that growth is assured by an expanding and more affluent population.
2. Belief that there is no competitive substitute for the industry's major product.
3. Too much faith in mass production and in advantages of declining unit cost as output rises.

4. Preoccupation with a product that lends itself to controlled scientific experimentation, improvement, and cost reduction.

Population Myth

The belief that profits are assured by an expanding and more affluent population is dear to the heart of every industry. If your product has an automatically expanding market, then you will not give much thought to how to expand it.

Petroleum and other industries that believe strongly in the beneficial consequences of an expanding population, and at the same time have a product for which there appeared to be no competitive substitute, seek to outdo their competitors by improving on what they are already doing. This makes sense, of course, if one assumes that sales are tied to the country's population strings.

Not even in product improvement has the petroleum industry showered itself with eminence. The greatest single improvement, development of tetraethyl lead, came from outside the industry. Big contributions made by the industry itself are confined to the technology of oil exploration, production and refining.

The industry's efforts have focused on improving the efficiency of getting and making its product, not really on improving the generic product or its marketing. Moreover, its chief product has continuously been defined in the narrowest possible terms, namely, gasoline, not energy, fuel, or transportation. This attitude has helped assure that:

> Major improvements in gasoline quality tend not to originate in the oil industry. Also, development of superior alternative fuels comes from outside the oil industry.
>
> Major innovations in automobile fuel marketing are originated by small new oil companies that are not primarily preoccupied with production or refining. These are the companies that have been responsible for rapidly expanding multipump gasoline stations.

Thus, the oil industry is asking for trouble from outsiders. Sooner or later, in this land of hungry inventors and entrepreneurs, a threat is sure to come. The possibilities of this will become more apparent when we turn to the next dangerous belief of many managements.

Idea of Indispensability

The petroleum industry is pretty much persuaded that there is no competitive substitute for its major product, gasoline—or if there is, that it will continue to be a derivative of crude oil, such as diesel fuel or kerosene jet fuel.

This is wishful thinking. The trouble is that most refining companies own huge amounts of crude oil reserves. These have value only if there is a market for products into which oil can be converted—hence the tenacious belief in the continuing superiority of automobile fuels made from crude oil.

Historic evidence shows that oil has never been a superior product for any purpose for very long and that the oil industry has never really been a growth industry.

First, crude oil was largely a patent medicine. Before that fad ran out, demand was expanded by use of kerosene lamps. Then suddenly the impossible happened. Edison invented a light totally nondependent on crude oil. Had it not been for the growing use of kerosene in space heaters, oil would have been good for little else than axle grease.

Disaster and reprieve struck again. Two great innovations occurred, neither originating in the oil industry. Successful development of coal-burning domestic central-heating systems made the space heater obsolescent. As the industry reeled, along came its most magnificent boost yet — the internal combustion engine, also invented by outsiders. When the demand for gasoline finally began to level off in the 1920's, along came the miraculous escape of a central oil heater. Once again, the escape was provided by an outsider's invention.

When that market weakened, wartime demand for aviation fuel came to the rescue. After the war expansion of civilian aviation, dieselization of railroads, and the explosive demand for cars and trucks kept the industry's growth in high gear.

Meanwhile centralized oil heating ran into severe competition from natural gas. While the oil companies themselves owned the gas that now competed with their oil, the industry did not originate the natural gas revolution, nor has it to this day greatly profited from its gas ownership. The gas revolution was made by newly formed transmission companies. As in the past, the industry was blinded by its narrow preoccupation with a specific product and the value of its reserves. It paid little or no attention to its customers' needs and preferences.

Management cannot find much consolation today in the rapidly expanding petrochemical industry, another oil-using idea that did not

originate in the leading firms. The total United States production of petrochemicals is equivalent to about 2% (by volume) of all petroleum demand. Although the petrochemical industry is now expected to grow by about 10% per year, this will not offset other drains on the growth of crude oil consumption. Furthermore, it is well to remember that there are nonpetroleum sources of the basic raw material.

Oil has grown by fits and starts, miraculously saved by innovations and developments not of its own making. Each time it thought it had a superior product safe from the possibility of competitive substitutes, the product turned out to be inferior and subject to obsolescence. Until now, gasoline (for motor fuel, anyhow) has escaped this fate. But it too may be on its last legs for there is no guarantee against product obsolescence. If a company's own research does not make it obsolete, another's will. Unless oil continues to be lucky, it can easily go down in a sea of red figures — just as the railroads and many other industries have. The best way for a firm to be lucky is to make its own luck. That requires knowing what makes a business successful. One enemy of this knowledge is mass production.

Production Pressures

Mass-production industries are impelled to produce all they can. The prospect of steeply declining unit costs as output rises is more than most companies can resist. Profit possibilities look spectacular. The result is that marketing gets neglected and great pressure is put on selling to get rid of what is produced.

The difference between marketing and selling is more than semantic. Selling focuses on the needs of the seller, marketing on the needs of the buyer. Selling is preoccupied with the seller's need to convert his product into cash; marketing with the idea of satisfying the needs of the customer by means of the product.

The usual result of this narrow preoccupation with so-called concrete matters is that instead of growing, the industry declines. Is this what is happening to the oil industry? Having let others steal marvelous opportunities from it (e.g., natural gas, as already mentioned, as well as missile fuels, and jet engine lubricants), one would expect it to have taken steps never to let that happen again. But this is not the case. We are now getting extraordinary new developments in fuel systems designed to power automobiles. These developments are concentrated in firms outside the petroleum industry, and petroleum is ignoring them, securely content in its wedded bliss to oil. It is the story of the kerosene lamp versus the incandescent lamp all over again. Oil is trying to improve hydrocarbon fuels rather than to develop any fuels best suited to the needs of their users, whether or not oil is the raw material.

These nonpetroleum companies are working on:

1. Energy systems which could replace the internal combustion engine and eliminate the demand for gasoline. Most are fuel cells designed to create electrical energy directly without combustion from chemicals, which are usually derived from hydrogen and oxygen.

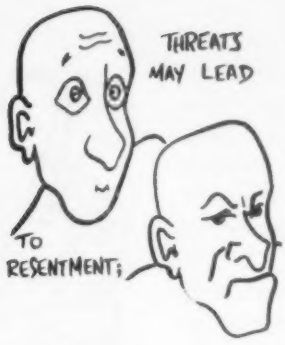
2. Other companies have advanced models of electric storage batteries designed to power automobiles. One is an aircraft producer who is working with several electric utility companies. Off-peak generating capacity could supply overnight plug-in battery regeneration.

3. Solar energy conversion systems are getting increasing attention. One usually cautious Detroit auto executive recently ventured that solar-powered cars might be common by 1980.

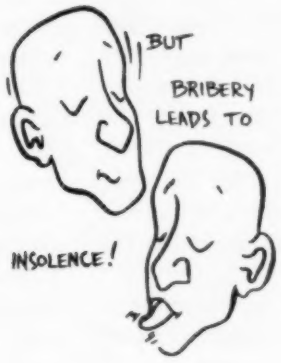
As for the oil companies, they are more or less "watching developments," as one research director put it to me. A few are doing a bit of research on fuel cells (powered by hydrocarbon chemicals). None are enthusiastically researching fuel cells, batteries, or solar power plants. None are spending a fraction as much on research in these profoundly important areas as they are on the usual run-of-the-mill things like reducing combustion chamber deposit in gasoline engines.

One might, of course, ask: Why should the oil companies do anything different? Would not chemical fuel cells, batteries, or solar energy kill the present product lines? The answer is that they would indeed, and that is precisely the reason the oil firms should develop these power units before their competitors, so they will not be companies without an industry.

Management might be more likely to do what is needed for its own preservation if it thought of itself as being in the energy business. But even that would not be enough if it persists in imprisoning itself in the narrow grip of its tight product orientation. Once the petroleum industry genuinely thinks of its business as taking care of people's transportation needs, nothing can stop it from creating its own extravagantly profitable growth. ■



A Fresh Look at Motivation



by A. Q. Sartain

Some of our accepted views of how to influence people have been jarred out of their ruts. We've learned common sense and manipulation have their limits. How do you best motivate subordinates, or influence your boss, your neighbor, or the members of your family? While we shall speak in terms of motivating subordinates, it should not be forgotten that this is only part of the story.

There are two methods of obtaining cooperation from a worker or work group. One is by threat of force — or its actual use — and the other is by persuasion, by getting the respondent to do what needs to be done because he wants to. There is no hard-and-fast line between these, for the threat of force may lead one to want to do a certain thing when without the threat he would not. Bribery may also be a form of motivation. But the essential difference is clear: Threat leads primarily to motivation because of the fear of external punishment whereas the other incentive comes from within the individual.

Nothing we say should be construed as suggesting that use of force as a means of getting productivity is always unwise. While use of force has been overdone in the history of the race, there is a place for it, and under some situations it will achieve highly desirable results not obtainable any other way.

For the last 20 to 30 years use of force has become unpopular and has probably not been used as frequently as it should have been. This has been true at work and even more so in the school and the home. Management, teachers, and parents, in other words, have been led to undue suspicion about its use, with the result that at times workers, pupils, and children in the home have gotten by with things that should have been prohibited.

Remember, though, use of force has definite limits. Order-giving builds dependence on the part of the subordinate and leads to resentment. The best one can hope for then is mediocrity and possible revolt. Furthermore, the recognition of individual rights, including the right to be self-determining, the less the method is useful.

Besides external (or imposed) motivation and internal motivation (or that which comes from within), there are two aspects of motivation.

First, there is the effect of policies (or goals), procedures,

practices, and rules of the organization. Thus in the work situation we must consider the wage structure, the state of communication both upward and downward, attitudes of workers toward values of management, fringe benefits, and physical conditions of work. At times these may be of paramount importance in influencing the enthusiasm of people in the organization.

Second, there are the effects of interpersonal relations within the work group, such as relationship between a supervisor and his immediate subordinates.

It is easy to get either of these sets of forces out of perspective. It has been popular to emphasize the role of the first-line supervisor in affecting the morale and determination of workers. We are sometimes told that he is the key person in effective motivation; that he is the company to the worker.

These are overstatements. Workers can thoroughly respect their immediate supervisors and still be most unhappy because of matters relating to the organization as a whole. Wage policies, fringe benefits, and other conditions of work may offset all the good efforts of supervisors, and a basic lack of faith in the moral integrity of top management may impose a burden that neither foremen nor good wages and working conditions can overcome.

You can't fight the Golden Rule.

Also, widespread acceptance of the fairness and competence of top management may largely neutralize the effects of poor supervision.

Let's examine the approaches to supervision and see how effective they are.

Everyone can advise on the "common sense" approach.

There are many axioms of "common sense." Sometimes these take the form of the Golden Rule: "Treat them as you would like to be treated." Sometimes they sound more like the Declaration of Independence: "Treat them all alike." The implication is that if men only have good motives and try to get along well, they will. Thus if management and union leaders were truly cooperative and understanding of each other, labor relations problems would disappear.

This is a difficult position to appraise and especially to criticize. After all one can hardly "come out against" goodwill and cooperation, and to suggest that the Golden Rule is not a sufficient guide to action is to raise doubts as to one's integrity.

But isn't this approach naive? Clearly we cannot treat all people alike because they are not all alike. And it is most unwise to treat another person as I would like to be treated if his wants, and his needs are radically different from mine. Obviously a spirit of cooperation is to be encouraged but life is so much more complex than this view contemplates. There are genuine conflicts in values in this world. Furthermore, the better you know some people, the more thoroughly you understand them, the less you like or even respect them. It must never be forgotten that the most bitter battles are fought between men of goodwill, with each side entirely convinced that the world's future is committed to its hands. Effective supervision may involve the Golden Rule, but it is certainly not just the Golden Rule!

Will these goodies get more done?

A bit less naive but still a part of the "common sense" approach to our subject is the "trait" approach. Here the question is asked, "What are the traits of a good leader?," and a blackboard can be filled in short order with the answers, "fairness," "knowing the jobs he supervises," "honesty," "going to bat for his people," "loyalty," and the like.

Such lists as we have mentioned are "arm-chair," and when they are put to the empirical test usually simply fail to distinguish between the more and the less successful leader. The traits tell us next to nothing about what to do. Surely we should all be fair, but what does that mean in concrete terms when one is faced with a demand for a wage increase, a new assignment, or a disciplinary penalty? The truth

is that "traits" are usually so generalized as to provide no basis for decision.

Thus we are forced to conclude that the "common sense" approach has little to recommend it.

Many have tried the "manipulative" approach. In this management does things to and for workers in order to get more from them: Changing (nearly always by raising) the wage scale, adding to "frir.ge" benefits, providing more desirable physical conditions of work and recreation activities for off-work hours.

In all these cases management may be attempting to entice or even "bribe" people to do more than they otherwise would. Perhaps the ultimate statement of this point of view is the oft-quoted expression, "The happy worker is the productive worker." If this is true it is obvious that management's job is to "keep 'em happy!"

This point of view at first seems quite accurate and useful but we begin to have some doubts if we pursue it to its ultimate conclusion. Paternalism may very well represent this point of view carried to its logical extreme. American workers usually accept the favors that management hands out, but they do not necessarily love or respect management more because of them. Indeed the very opposite may be true!

Paternalism has failed in this country for the same reason that any manipulative approach is likely to fail: It undermines and eventually robs a person of his self-respect.

We are dealing here with a fundamental moral or ethical issue. If management's only real interest is to get out production the most effective type of cooperation is impossible. People virtually always resent it when they are being used or "engineered" in spite of how much they are being paid to endure the situation.

Advice to "keep them in the know" is an example. Workers are supposed to be kept "in the know" not because of their intrinsic worth as human beings or because of any inherent right to know, but in order to get out more production.

Confiding in the subordinate may be poor advice also because in most human situations there is information which should be kept secret. If divulged it might easily be misunderstood or misused.

Don't tell everything.

Reasonable and wise sharing of information with one's subordinates is no doubt both expedient and wise; a naive sharing might be disastrous.

Another illustration of a manipulative technique is often called to the supervisor's attention: "Show them what there is in it for them." The point of view is that it is management's job to show people how they will gain if they do what management wants.

We in America have been greatly influenced by this doctrine, not only in appraisal of the activities of workers but also for other economic goals. Thus some of us have not only said "The only way to a worker's heart is through his pocketbook," but we have also said that "Every man has his price," "Every man for himself and the Devil take the hindmost." We have also asserted that management is always and ultimately interested in profits, and that unions are always concerned primarily with Samuel Gompers' famous "More."

There is a related area of emphasis on man's rational processes, for business has traditionally emphasized enlightened self-interest. Thus we have stressed man's logical processes and assumed that a significant, wise influence on these processes will work wonders.

But emphasis on self-interest from management has often created suspicion on the part of workers. Rational appeal and the appeal to self-interest ignore the fact that we are creatures of feeling just as truly and significantly as we are creatures of reason. Valuable as the rational approach is at times, at other times it should be modified (or abandoned). For example, we all have important unconscious motives and these may be appealed to; our sense of loyalty and devotion to our organization may motivate us more strongly than any so-called "fact."

Likewise we overlook certain often-neglected needs of people, among them the need to be needed, the need to belong, and the need to keep and improve one's own self-respect. That these are all real and significant needs is proved every day in business and industry.

It is one thing to analyze present approaches to a problem and discover their strengths and weaknesses, and quite another to

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find a practical alternative. One possible way to begin our search is to look at some findings of research studies.

The Survey Research Center of the University of Michigan has conducted several significant research projects. One was conducted in the Newark office of The Prudential Insurance Company and later studies gave approximately the same results in a number of diverse work situations.

The study was built around matched work groups doing the same work and having no significant differences in demographic characteristics but differing in productivity. Thus a particular pair had the same number of men and of women, the same average age, the same number of years of formal schooling, the same average salary, the same number of years with Prudential, the same average score on some psychological tests, and were doing the same thing to the same kinds of pieces of paper. In actual production records kept over a period of several months, however, a considerable difference in productivity was found. We shall henceforth refer to the more efficient group of each pair as the "high" group and to the less efficient as the "low" group.

A salient finding with regard to the groups (as opposed to the supervisors) was that "high" groups usually had more group

pride than did "low" groups. It may be equally important that there were no significant differences between "high" and "low" groups in suggestions from the company, participation in recreational programs, and an over-all measure of "happiness." This failure to find such differences may be as meaningful as any real differences found. If the situation is typical many management policies and procedures will have to undergo close examination.

There were definite differences between "high" and "low" supervisors though not in the areas where they might be expected. Thus, there was no relationship between "success" in supervision and age, education, sex, salary, or amount of experience of the supervisors. But there were important differences in behavior and attitudes of "high" and "low" supervisors.

For one thing, "high" supervisors usually supervised in a general fashion while "low" supervisors usually supervised tightly. (Incidentally, "high" supervisors were themselves usually supervised generally, while "low" supervisors were usually supervised closely.)

While "high" supervisors usually supervised more generally than "low" supervisors, they spent decidedly more time in supervision.

Third, when a new task was given to the worker, the "low" supervisors and not the "high" ones did the more thorough, detailed job explaining it.

You don't need a platform.

The "low" supervisor and not the "high" made the larger number of recommendations for salary increases, promotions, etc. (However, the "high" supervisor had the higher batting average on such recommendations.)

The company had separate dining rooms for supervisors and non-supervisory personnel and when questioned about this, "high" supervisors expressed dislike of the arrangement, while "low" supervisors generally approved or were indifferent.

A widely publicized finding of the investigation was that "high" supervisors were more critical of the company. It is interesting what they criticized most: The merit rating program and the promotion policies, the very things that one would expect ambitious people to criticize.

Careful notes were kept on what supervisors usually talked about when they chose the topic of conversation. "High" supervisors characteristically talked about their subordinates, while "low" supervisors characteristically talked about quotas, deadlines, methods, costs. In other words, "high" supervisors were employee-centered while "low" ones were work-centered.

What does our experience to date indicate about the attributes of the successful leader?

First, the more successful supervisor has more confidence in his subordinates. This confidence takes the form of high expectations about their performance. Such a leader believes that his people are sincere and capable and that they will do a good job.

Remember this is not affected so much by the tasks he sets before them or what he tells them he expects of them. It is a response to deep feeling, sometimes unconscious feeling.

Although not generally known, the expectations of a leader as to the performance of his subordinates sets an effective ceiling beyond which they are not likely to go. They may disappoint him, not reaching the levels he sets for them; they seldom exceed them. If this is true it suggests that management's pessimism about the nature of today's worker is an important factor in keeping down achievement.

Second, the successful supervisor has learned that people cannot be engineered successfully.

Man isn't easy to "engineer."

He is committed to the belief that people have an intrinsic value, and not merely an extrinsic or instrumental one to serve his ends or those of his employer.

This also says that such a leader recognizes and is committed to certain basic ethical and moral values, values which he attempts to preserve even if such action is not always profitable to him personally. A leader must realize that no matter how attractive he is, no matter how high his I.Q., or his competence, if his subordinates do not trust him as an ethical individual devoted to certain values bigger than his own self-interest they

can never follow him with enthusiasm.

Third, he has confidence in himself. He believes, as we have said, that his employees will do a good job. But he also believes that if they fail to do so, he will discover the situation before it is irretrievably lost and that he has ability to salvage the situation.

In the points mentioned we find an explanation of a contradiction on delegation of authority that plagues so many organizations. At practically all levels the managers "talk a good game" about delegation and frequently play a poor one. The explanation is not hard to find: Delegation is primarily a matter of emotional commitment. To delegate in any real or meaningful sense a leader must believe in his group and in himself and have high expectations of both.

Fourth, the successful leader feels psychologically comfortable in the presence of his subordinates. He not only "likes people," as we all seem to feel we do; he likes to be with people. Instead of being shy or reticent or fearful when with his people, he enjoys his association with them. Instead of needing to talk about something cold and impersonal he feels free to talk about feelings, ideals, and judgments. And instead of being under compulsion to dominate a conversation and express his own ideas by talking to his subordinates, he is sufficiently comfortable that he can talk with other people, including his subordinates.

Finally, and almost as a corollary of the point just discussed, the successful leader has learned not to take himself too seriously. He has learned and has accepted emotionally that some of his subordinates know he is far from perfect and indeed believe that if

Resourceful managers have confidence.

only they had his job, they could do it much better. He also believes that it is from such critical employees that future leadership is likely to come.

The way one feels about his boss is usually the same way one's subordinates feel about him.

No matter how good a supervisor he is he simply cannot "please them all." Knowing this, successful supervisors may reach the stage where they can relax and enjoy the foibles of their fellow human beings—and themselves.

About the Author

Dr. Aaron Quinn Sartain is professor of psychology and industrial relations at Southern Methodist University and director of graduate studies in management, School of Business Administration. Since 1932 he has been on the faculty of SMU, where he received his BA and MA degrees. His PhD is from University of Chicago. A Fellow of American Psychological Association and of American Association for Advancement of Science, Dr. Sartain is also a management consultant. He is co-author of two books on human behavior. ■

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Sept. 11-15—ISA Fall Instrument-Automation Conf. and Exhibit and ISA's 16th annual, Sports Arena, Los Angeles, Calif.
Sept. 12-14—National Petroleum Assn., annual, Traymore Hotel, Atlantic City, N. J.
Sept. 13-15—Mid-Continent Oil & Gas Assn., Lou.-Ark. Div. 39th annual, The Roosevelt Hotel, New Orleans, La.
Sept. 13-15—PCGA, convention and annual meeting, Coronado Hotel, Coronado, Calif.
Sept. 14—Natural Gasoline Assn. of America, Rocky Mountain regional, Northern Hotel, Billings, Mont.
Sept. 14-15—ASME-AIEE, engineering management conf., The Roosevelt Hotel, New York City.
Sept. 17-20—American Institute of Electrical Engineers, annual electrical conf. of the petroleum industry, Jung Hotel, New Orleans, La.
Sept. 20-21—Western Petroleum Refiners Assn., Rocky Mountain regional technical-industrial meeting, Henning Hotel, Casper, Wyo.
Sept. 24-27—ASME, petroleum mechanical engineering conf., Hotel Muehlebach, Kansas City, Mo.
Sept. 24-28—ASTM Committee, D-2 meeting, Statler Hotel, Detroit, Mich.
Sept. 25-27—Texas Mid-Continent Oil & Gas Assn., 42nd annual, Texas Hotel, Fort Worth, Tex.
Sept. 25-28—American Welding Society, fall meeting, Adolphus Hotel, Dallas, Tex.
Oct. 1-4—AGA, annual convention, Dallas, Tex.
Oct. 4-6—American Assn. of Oilwell Drilling Contractors, 21st annual, Rice Hotel, Houston.
Oct. 4-6—ASME, process industries conf., Shamrock-Hilton Hotel, Houston.
Oct. 8-11—Society of Petroleum Engineers of AIME, 36th annual fall meeting, Memorial Auditorium, Dallas.
Oct. 17-19—ASME-ASLE, lubrication conf., Morrison Hotel, Chicago, Ill.

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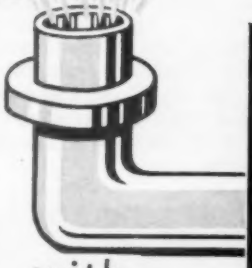

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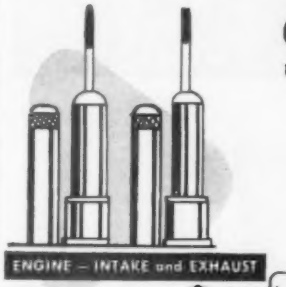

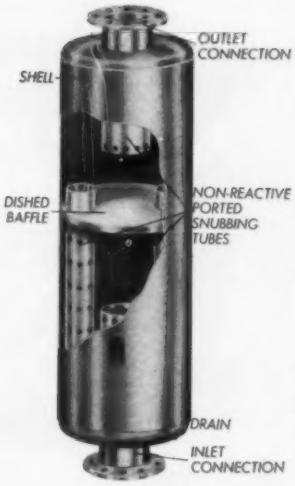

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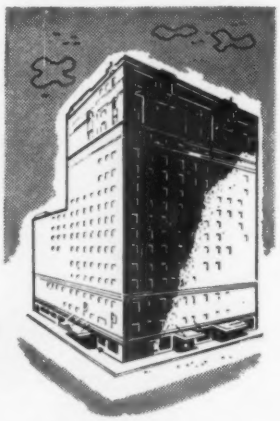
Management People

New officers and directors of Petroleum Electric Power Association for 1961-1962 are shown below: Fred Woerner, Texas Electric Service; R. W. Williams, Community Public Service; secretary-treasurer Herb Winters, Oklahoma Gas & Electric; W. M. Larkin, Gulf States Utilities; president B. F. Thompson, Public Service of Oklahoma; Bill Ohrman, Texas Power & Light; vice president Kirby Dawkins, West Texas Utilities; Harold Nay, Kansas Gas & Electric; Roger Owen, Southwestern Public Service; and J. D. Reed, New Mexico Public Service. Not shown are directors Julian Taylor, Houston Lighting & Power and H. P. Lindsey, Arkansas Power & Light.

Patricia L. Brown, information services supervisor for the semiconductor-components division of Texas Instruments, Dallas, was elected president of the Society of Women Engineers. She is the first woman engineering graduate of the University of Southwestern Louisiana.

Edward Barnes, former executive vice president of Macmillan Petroleum Corporation, joined Edgington Oil Refineries, Inc. as vice president of domestic sales. K. W. Kendrick Jr. is vice president, foreign sales.

Jean B. Dumon, who has held major positions in French industry, was appointed president-director-general of Burgess-Manning, International, S.A., Paris, France. The subsidiary of Burgess-Manning



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Thomas D. Durrance was elected vice president of public relations for the Arabian American Oil Company. He succeeds H. O. Thompson, who will serve as a consultant. Durrance will remain in the Middle East where he has been manager of the public relations department.

T. D. Durrance

H. Wilkinson

H. Wilkinson was elected a member of the board of directors of Shell Oil Company replacing F. J. Stephens who resigned to become chairman of the board of Shell Transport and Trading Company, Ltd. Wilkinson began his Shell career in 1922. He has been president of Asiatic Petroleum Corporation and Canadian Shell Ltd.

William E. Dickinson of Sun Oil Company retired after 35 years with the firm. He served as assistant division operating superintendent in charge of the mechanical and electrical department and division superintendent of the communications department. His former Gulf Coast production division duties were assumed by Eugene H. Wilder who was named group supervisor of mechanical and electrical activities, operating department, and manager of the communications department.

William P. Conway, former administrative assistant to the president, was appointed assistant to Paul G. Benedum, president of Plymouth Oil Company. The new executive position was created to expedite handling of administrative matters and prompt application of executive policy.

Major J. R. Parten, special consultant to the Secretary on oil and gas matters, Department of the Interior, resigned. A charter member of the National Petroleum Council and Petroleum Industry War Council, he served under four Secretaries of the Interior. George T. Goggin, executive vice president of Douglas Oil Company of California, was appointed to the National Petroleum Council which acts in an advisory capacity to the Federal Government through the Secretary of the Interior and its office of oil and gas.

Ed Overholser of Austin was appointed assistant executive secretary of the Interstate Oil Compact Commission, announced Governor Price Daniel, IOCC chairman. Overholser is associated with Lawrence R. Alley, IOCC executive secretary, headquarters in Oklahoma City.

Max R. Dodson, former vice president, controller and assistant treasurer for Lone Star Steel Company, assumed new duties as one of two executive vice presidents. Howard Jensen, former vice president, legal, was elected vice president, general counsel and corporate secretary.

L. A. Smith, former assistant coordinator of producing activities for Jersey Standard, was named deputy coordinator of producing activities succeeding Zeb Mayhew, who was elected a director and executive vice president of International Petro-

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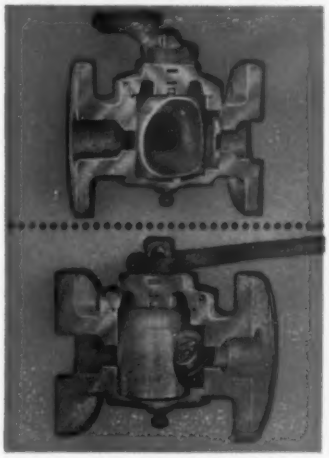

Cut-away illustrates **PLUGAROO** with plug "closed" (top) and as check valve "open" (bottom).

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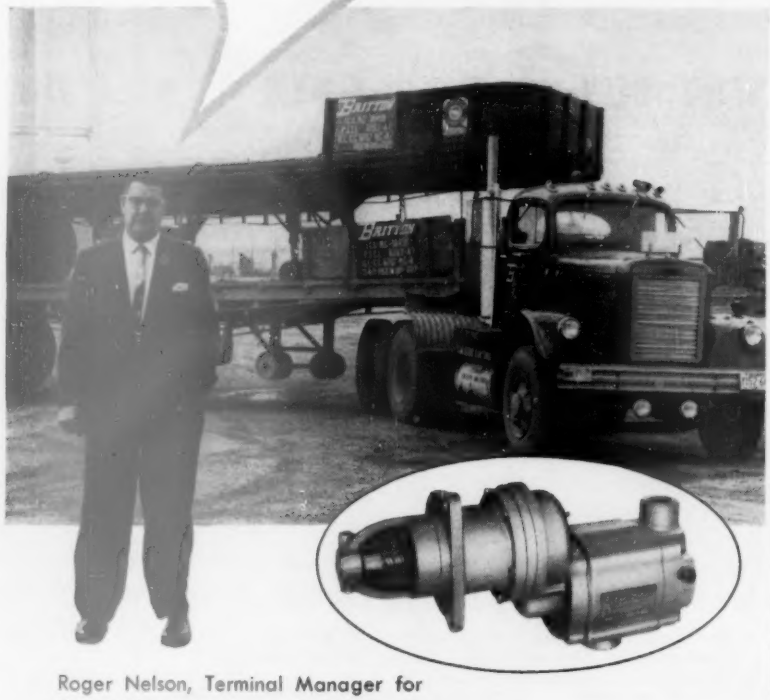

Roger Nelson, Terminal Manager for Britton Motor Service at their Chicago base has this to say about Ingersoll-Rand Air Starters...

"Your Size 9BM Air Starter was applied to one of our Cummins diesel powered White trucks. This truck was in operation for five years and accumulated in excess of 700,000 miles. We are very satisfied with the service life and operation of your Air Starters. The newer Size 10BM we now have in service has even more power."

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leum Company, Jersey Standard affiliate. Smith is succeeded by W. J. Barnett who is replaced by J. F. Moore Jr., as producing advisor for Europe, Mediterranean countries and West Africa.

George T. Piercy, Standard Oil Company (New Jersey), former manager of Jersey Standard's coordination and petroleum economics department, succeeded Chadwick H. Carpenter as executive assistant to M. J. Rathbone, president and chief executive officer of the company. Carpenter was elected a director of Esso Mediterranean, Inc., headquarters in Geneva, Switzerland.

G. T. Piercy

P. J. Wolfe

Paul J. Wolfe, manager of the operations analysis department, Mobil International Oil Company, an operating division of Socony Mobil, was promoted to the newly created position of planning manager. Wolfe went with the company from Texas A&M in 1942 as process engineer and has moved up to his new post through successive positions.

Clifford B. Marshall, executive vice president of Standard Vacuum Oil Company, (Socony and Jersey Standard) was named president succeeding Harry F. Prioleau, retired. J. A. McQuilin, vice president, was elected executive vice president.

Lewis E. Albright, supervisor of basic research in the employee relations research division, American Oil Company, was awarded the Diploma in Industrial Psychology.

Lawrence A. Kimpton, director of Standard Oil Company (Indiana), and Albert L. Nickerson, president, Socony-Mobil Company, Inc., are among the 29 new members of the board of trustees of the Committee for Economic Development. The CED is a group of 200 leading businessmen and university presidents who conduct research and develop policy recommendations on major economic issues and sponsor education on American economy.

Colonel Willard F. Rockwell, chairman of the board of both Rockwell Standard Corporation and

Rockwell Manufacturing Company, was elected chairman of the Council of Trustees (governing body of the Association of the United States Army) for the third time in the past five years. He is the only individual ever to hold this office for more than one term.

Earle Marshall, a vice president of Empire Trust Company, New York, was elected to the board of directors of White Eagle International, Inc., oil producing and engineering company. Headquarters are in Midland, Texas.

Atholl McBean, widely known civic and business leader, resigned from the board of directors of Standard Oil Company of California after 19 years service.

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Management Books

The Stages of Economic Growth, by W. W. Rostow. Published by Cambridge University Press, 32 E. 57th Street, New York 22, New York. Pages, 179. Price, cloth edition $3.75; paper edition $1.45.

W. W. Rostow is a professor of economic history of Massachusetts Institute of Technology. He compares Russian and American growth and finds the communists solution to the problem of linking economic and non-economic behavior unsatisfactory. He points out, however, that there is no major culture, including the Russian and Chinese, which does not in its own way make allowance for the uniqueness and diversity of men, and provide in its structure and canons, for balance and for private areas of retreat and expression.

Sampling in a Nut Shell, by Morris James Slonim. Published by Simon and Schuster, New York. Pages, 145. Price, $3.50.

You can't get away from opinion takers today. Mr. Slonim, who is in statistical work with the U. S. Air Force and lecturer in statistics at George Washington University, gives managers in private industry some understandable information on sampling. This small volume is recommended for its practical value to managers who want to get information quickly, reliably, and cheaply. Written in a light-hearted fashion, Slonim takes you through many phases of sampling without straining your mathematical facilities. Sprightly drawings by Paul Coker help the book's readability.

Blazer and Ashland Oil, by Joseph L. Massie. Published by the University of Kentucky Press, Lexington, Ky. Pages, 253. Price, $5.

This is sub-titled "A Study in Management" and is an excellent account of the rise of Paul G. Blazer who organized Ashland Oil and Refining Company and guided it during 33 years of successful operation. Mr. Massie does not agree that administrative principles suitable for large organizations are valid for small businesses. He concludes that Ashland Oil's rapid growth is attributable to practices strikingly at variance with accepted principles of corporation management. He shows that flexibility was the key principal of Blazer's policies, which enabled the expanding company to compete successfully in the market. The author is a professor of economics at the University of Kentucky. His study of the Ashland organization and its management will be of interest to petroleum managers everywhere.

Ends and Means of Modern Management. Published by American Management Association, 1515 Broadway, New York 36, New York. Pages, 158. Price, $3.75; to AMA members $2.50.

Contains 16 short articles directed to modern management. Exercise of skilled leadership and functional efficiency is not enough for today's rising production costs and world-wide competition. The professional manager needs also to strive for improvement in the environment where corporal survival and profitability is carried on. He must also understand and influence economic, technological, social and political forces which shape this external environment. Such subjects as "Business, Politics, and Survival" by William M. Allen, president of Boeing Airplane, indicate approach of the report.

Marinas-Recommendations for Design Construction and Maintenance, by Charles A. Chaney. Published by National Association of Engine and Boat Manufacturers, Inc., 420 Lexington Avenue, New York 17, New York. Pages, 247. Price, $7.50.

The oil industry has found Marinas a new source of income and this book should inspire increased building of the modern water front facility for recreational boats. The marina answers the boatman's need for a center of activity where he can berth, launch, repair, fuel and provision his boat conveniently. The author is an authority on marinas and a professional engineer, whose firm has designed hundreds of them all over the country.

Your Government Notebook, by Robley D. Stephens. Published by W. A. Wile Company, Boston, Massachusetts. Pages, 168. Price, $4.50.

Here's a good book for anybody who is going to Washington, D. C., or who has dealings with agencies there. It is simple enough for schools. It is also complete enough to provide a reference on the federal government center. There are over 80 illustrations.

Twentieth Century Common Sense and the American Crisis of the 1960's. Published by American Institute for Economics Research, Great Barrington, Massachusetts. Pages, 95. Price, $1 for 1; $2 for 3; $5 for 10 copies.

The title is borrowed from Thomas Paine's "Common Sense" of 1776 but the author's American Institute for Economic Research editorial staff declare it is not a call to arms, as the earlier pamphlet, but an invitation to think. Conservative economics linked only to a political minority can be powerful enough to prevail, the authors claim. Chapter headings indicate the tone: "Stand Still, Little Lamb, to Be Shorn," "The Counterrevolution," "Putting Friends in Socialists Straitjackets."

Alaska, U. S. A., by Herb and Miriam Hilscher. Published by Little, Brown and Company, 34 Beacon Street, Boston 6, Massachusetts. Pages, 243. Price, $4.50.

With the recent flurry of oil activity in the 49th state this good source on Alaskan life will be valuable reading for those already in the area or planning to go there. It describes the geography of the country, its social life, community organizations, and has a chapter on "How Oil Came to Alaska." The authors are old Alaskan hands. Mr. Hilcher is in the public relations business in Anchorage and is identified with the petroleum industry in the state.

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CONVEYORS • LOADERS • DITCHERS • ASPHALT PAVING EQUIPMENT

Operations for 75 Companies

By Ernestine Adams

TABLES on oil and gas operations of the 75 companies covered in our annual survey reveal some interesting totals.

The 42 concerns with refining capacity made about 96% of crude runs to stills in 1960. These companies refined 7,782,123 b/d and total U. S. runs were 8,073,000 b/d. Two companies, Leonard Refining and Macmillan, do not appear in Table 2, which covers drilling and production.

U. S. oil production for the group drops to 65% of the 1960 total — 4,598,671 b/d. The remainder of the 7,054,600 b/d oil produced is credited to companies not publicly owned and to individuals, both producers and royalty owners. This amounts to nearly 2½ million barrels a day.

The 35 companies with oil production abroad account for 5,231,000 b/d or 45% of the total "free world" output, excluding the USA.

LPG production for our group is 55% of the U. S. total. Natural gas production represents 56% of natural gas output.

When we come to drilling, however, the story is different. The 12,000 net wells drilled by the 75 companies surveyed represent only about one-fourth of the total drilled in 1960 in the USA. That means independents (excluding those in the group) drilled 75% of the wells in 1960 — field and exploratory.

Discoveries, as given by the companies themselves, were one for 3.4 exploratory wells. This is a great deal better percentage for success than the one for 9 ratio commonly quoted. There are several reasons for this — the word "wildcat" or "exploratory" is an elastic term. Then, too, a report to stockholders, from which these data are taken, is inclined to be written by the optimist. Some of these discoveries may end up not quite commercial. Note that several large companies do not give wildcat figures and that the figures include foreign exploration wells.

Table 1. Refinery Operations in 1960.

	No. refineries	Crude oil capacity b/d		Crude runs b/d	
		U.S.	Foreign	U.S.	Foreign
American Petrofina	3	50,000		36,207	
Anderson Prichard	2	37,500		30,303	
Ashland O & R[6]	6	175,000		146,586	
Atlantic Ref	2	210,000		191,764	1.253
Champlin O & R	1	31,000		27,124	
Cities Service	5	313,000		266,292	
Clark O & R	1	35,000		30,817	
Colorado O & G	1	20,000		17,014	
Continental		193,200		181,927	
Cosden Pet.	2	43,000		39,534	
Delhi-Taylor	2	51,000		42,784	
Douglas of Calif.[1]	3	20,000		17,500	
Frontier Refining[8]	3	30,700		22,000	
Getty Oil	2		90,000		46,121
Gulf Oil	5	562,557[9]		479,000	280,000
Kerr-McGee[7]	4	55,000		42,555	
Leonard Refining	3	29,000		25,446	
Macmillan Pet.	2	13,000		10,859	
Murphy Corp.[2]	1	15,000		12,432	
Ohio Oil	3	110,000		100,066	
Pauley Pet.[2]	1	4,500		4,000	
Phillips Pet.		274,300	23,900	217,000	13,000
Plymouth Oil	1	45,000		25,355	
Pure Oil	4	187,000		166,984	
Quaker State	3	10,300		8,020	
Richfield Oil	1	165,000		148,331	3,680
Shamrock O & G	1	25,000		22,333	
Shell Oil	6	594,000		501,000	
Signal O & G	2	80,000		70,000	
Sinclair Oil		489,000	35,000	418,688	17,295
Skelly Oil	3			48,865	
Socony Mobil	19	716,700	260,400	572,000	202,000
South Penn	1	12,000		9,884	
Standard Cal.		712,500[3]		485,036	350,511
Standard Ind.	12	720,400		636,326[5]	
Standard N. J.	58			815,000	2,056,000
Standard Ohio	2	170,500		137,306	
Sun Oil	3	255,000	18,000	209,113	16,178
Sunray Mid-Cont.	3	175,000		148,145	
Texaco Inc.		1,082,800		1,006,500[3]	320,864[4]
Tidewater Oil	2	280,500		240,000	
Union Oil Calif.	6	188,800		161,627	
TOTALS				7,782,123	3,321,902

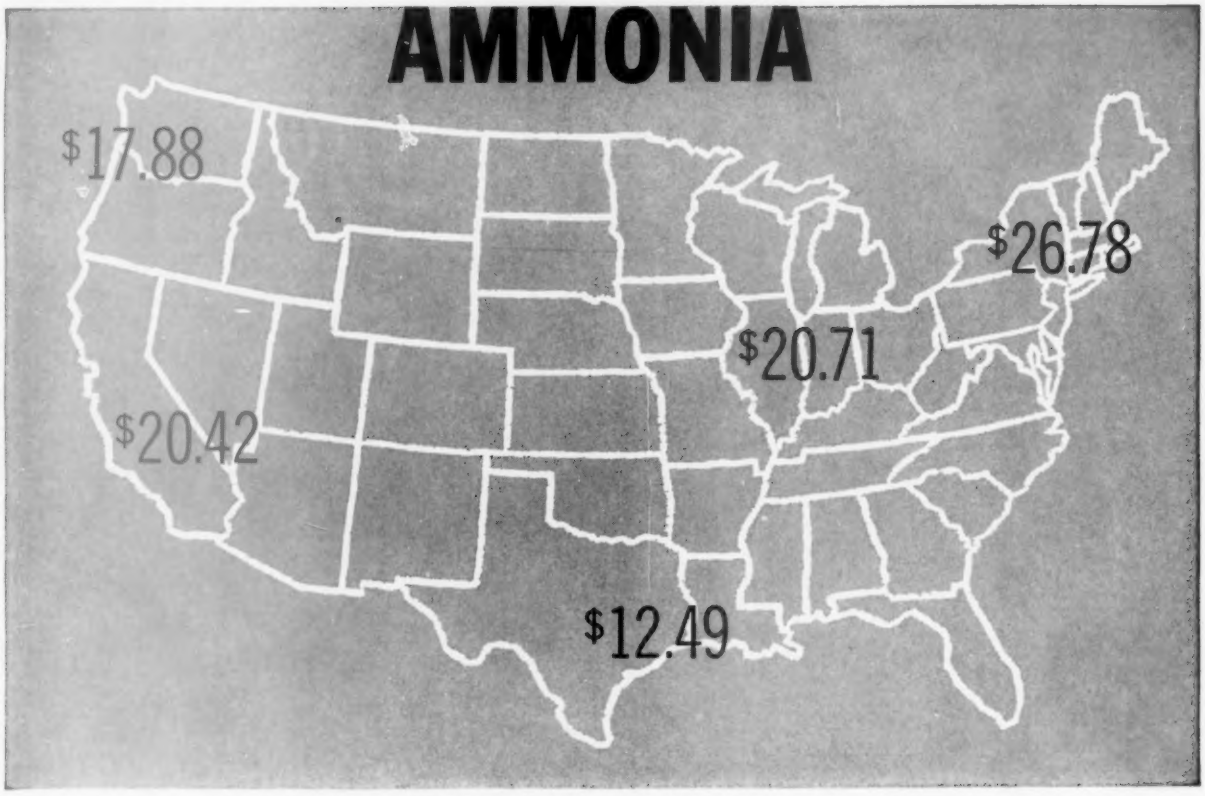
[1]Now part of Continental Oil Company
[2]For 7 months ending Dec. 31, 1960
[3]West. Hemisphere
[4]East. Hemisphere
[5]Includes natural gas liquids
[6]Fiscal year ending Sept. 30, 1960
[7]Fiscal year ending June 30, 1960
[8]Fiscal year ending May 31, 1960
[9]Including Wilshire.

Table 2. Drilling and Producing Operations in 1960.

Company	Net lease or fee, dev. or undev., 1000 acres		Net wells drilled		Net producers		Wild-cats, net	Dis-cover-ies, net	Net pro-ducing wells owned	Net Production			
										Crude oil b/d		U. S. LPG b/d	Gas MM cf/d
	U. S.	Foreign	U. S.	Foreign	Oil	Gas				U. S.	Foreign		
Ambassador	507	208	48	6	19	5	35	14	401	5,158	39	—	10
Amerada	6,582	120,828	174	—	75	18	—	—	3,570	80,879	—	—	296
Am. Petrofina	544	—	29	—	17	1	9	2	1,174	8,182	—	—	46
Anderson-Prich.	1,044	174	83	4	57	5	20	7	—	14,169	49	—	43
Argo Oil	788	—	37	—	12	6	19	2	502	13,345	—	—	49
Ashland[28]	314[1]	—	89[1],	3	45	8	18	4	3,107	7,710	5,095	—	10
Atlantic Ref.	6,379[1]	10,874	127[1]	13	74	27	32	11	4,766	97,684[1]	55,008	—	587
Aztec	649	—	89	—	61	18	7	—[8]	460	6,050	—	—	48
Bishop Oil[17]	12	8[19]	2	—	—	—	2	—	—	1,378	1,089[19]	—	3
Champlin	1,351[1]	508	63	33	51	10	25	5	—	15,069	—	9,548	266
Cities Service	4,860	1,577[19]	265[1]	—	—	—	—	—	—	125,160[1,14]	—	—	884
Clark O & R	222	2,412	—	—	—	—	—	—	—	—	—	—	—
Coastal States[26]	174	—	73	—	8	53	10	6	201	463	—	315	29
Colorado Oil	916	163[19]	44	13	39	7	13	6	828	6,000	1,551[19]	—	42
Continental	8,660	—	597	—	421	36	94	19	—	156,274	—	12,562	441
Cosden Pet.[25]	187	—	47	—	26	9	17	7	551	5,638	—	—	9
Delhi-Taylor	445	131,332	49	1	11	31	12	9	—	5,505[14]	962	962	140
Drilling & Exp.	295	250	22	1	9	2	11	3	—	3,345	—	140	7
Eason Oil[18]	130	—	9	—	5	—	3	1	268	1,400	—	—	5
Frontier Ref.[29]	279[1]	—	19[1]	—	14	3	1	1	80	1,282	—	—	—
Gen. American[26]	410	410[19]	62	5	51	5	12	4	3,164	21,984	2,170[19]	—	13
General Crude	1,465	—	38	—	10	2	24	4	483	8,300	—	—	21
Getty Oil	303	—	14	41	48	—	—	—	—	8,565	70,145	231	11
Gulf Oil	12,673	74,898	986	159	784	102	192	58	—	343,736	1,119,792	112,811[6]	1,148[7]
Helmerich(H&P)[23]	295	230	41	—	30	2	7	0[8]	513	4,867	—	—	22
Honolulu Oil	1,571	2,708[19]	79	18	73	5	24	7	—	41,100	5,900[19]	3,060	61
Hugoton Prod.	130	—	5	—	—	5	—	—	169	—	—	—	35
Intex Oil	109	—	19	—	6	1	12	—	140	2,249	—	—	—
Kerr-McGee[26]	1,219	348	42	6	27	11	10	4	38	5,214	1,944	3,878	147
Kewanee Oil	785	165	75	47	63	8	28	9	—	18,709	1,642	—	—
La. Land & Exp.	886	—	14	—	10	1	3	1	126	29,252	—	—	83
Maracaibo	6	—	2	—	2	—	—	—	215	812	96	680	3
Midwest Oil	712	17[19]	38	4	21	4	16	4	910	17,956	165[19]	—	43
Murphy Corp.[10]	1,257	—	20	—	11	2	0[8]	0[8]	459	14,779	—	0[9]	55
Ohio Oil Co.	2,966	34,202	252	40	241	3	38	10	8,052	93,522	6,071	11,277	285
Olin O & G	600	—	76	—	32	32	9	4	652	3,113	—	644	100
Pauley Pet.[10]	—	—	9	24	—	—	—	—	—	1,654	2,362	—	47
Phillips	6,232	35,324	269	42	147	72	27	5	8,944	120,000	58,000	102,500	2,886[13]
Plymouth Oil	468	30,148	23	7	9	2	19	2	1,356[6]	13,290[1]	—	—	108
Producing Prop.[27]	27	1	4	—	4	—	—	—	908	10,017	—	—	35
Pubco Pet.	503	—	22	—	14	6	4	3	110	1,313	—	70	24
Pure Oil	4,899[1]	1,102	162[1]	—	90[1]	15[1]	46[1]	12[1]	5,228[1]	68,574[1]	7,411	4,738	313
Quaker State	80	—	140[11]	—	—	—	—	—	—	1,377	—	—	—
Republic Nat.[26]	—	—	47	—	23	12	5	4	1,132	7,606	—	—	179
Richfield Oil	1,639	4,192[19]	78	4	79	3	33	3	1,513	64,024	12,583	—	—
Shamrock Oil	734	—	133	—	36	65	80	54	1,239	5,118	—	9,441	221
Shell Oil	13,994	—	970[5]	—	751[5,12]	—	166[5]	49[5]	9,903	320,000	—	32,800	1,064
Signal O & G	661	—	61	20	57	1	2	—	1,266	32,700	42,000	12,400	29
Sinclair Oil	9,476	903	305[1]	8	171	43	81	21	9,211[1]	120,744	43,100	18,213	431
Skelly Oil	5,471	78[19]	213	55	190	26	29	6	5,634	61,249	1,947[19]	22,203	340
Socony Mobil	14,441[1]	—	332[1]	—	231[1]	38[1]	45[1]	12[1]	15,186[1]	228,469[1]	483,034	26,000	998[1]
Southland Rlty.	440	44	44	—	19	8	6	1	—	8,050	—	—	—
South Penn	907	—	331	—	164	3	—	—	—	8,596	—	—	—
Standard Cal.	10,388	101,486	606	65	507	37	78	28	10,380	297,762[14]	630,537	—	703
Standard Ind.	16,569[1]	—	963[7]	—	605[7]	115[7]	196[7]	57[7]	13,958[7]	285,972[14]	33,022[14]	—	1,577
Standard N. J.	21,873	186,932	954	484	903	147	340	96	27,100	442,000	1,999,000	63,000	1,560
Standard Ohio	1,148	2,966	63	2	36	8	14	5	1,921	25,057	10,707	3,585	99
Sun Oil Co.	9,672	7,450	363[1]	7[1]	200	52	—	—	4,471	113,760[1]	36,177	—	675
Sunray Mid-Cont.	6,376	26,705	247	11	145	29	69	15	5,089	71,246	8,280	9,193	414
Sunset Inter'l.[37]	76	—	—	—	—	—	—	—	540	4,728	—	—	13
Superior Oil[27]	380[21]	6[21]	—	—	—	—	—	—	2,623[21]	71,182	21,878	8,241	639
Tekoil Corp.	32	—	25	—	19	—	—	—	402	2,356	—	—	6
Texaco Inc.	14,105	38,508	1,376	241[23]	1,202[15]	169[15]	—	—	—	790,152[15]	562,203[16]	—	1,404
Texas Gulf	184	—	22	—	19	—	7	5	—	12,050	—	1,250	31
Texas Nat'l Pet.	624	—	45	—	5	22	9	4	418	4,456	—	—	39
Texas Pacific	1,126[1]	—	109	—	87	10	13	5	1,755	20,230	—	828	99
Three States[24]	800	6,430	29	3	12	11	7	1	—	3,288[14]	—	—	41
Tidewater	2,059	11,112	335	13	305	13	22	5	5,793	89,652	7,190	17,505	388
TXL Oil	1,973	—	67	—	38	3	16	1	371	10,925	—	—	28
Union Oil Calif.	2,319	1,500	184	37	129	34	65	19	4,376	91,954	3,490	7,175	353
Union Tex. Nat.	2,028	704	19	16	17	4	12	1	196	9,446	6,180	23,548	236
Universal Cons.	281	—	12	—	7	1	5	1	309	7,500	—	—	17
Wilcox Oil	183	—	41[5]	—	24[5,12]	—	15[5]	1[5]	555[5]	3,323	—	—	7
TOTALS	—	—	12,232	1,433	8,598	1,371	2114	618	—	4,623,469	5,231,119	518,798	19,946

[1]U.S. and Canada
[5]Gross
[6]Sales
[7]U.S. and foreign
[8]Inc. in field wells
[10]For 7 months ending Dec. 31, 1960
[11]New or renovated
[12]Oil and gas wells
[13]Sold or consumed
[14]Inc. natl. gas liquids
[15]West Hemispheres
[16]East Hemisphere
[17]Acquired by Shell Oil
[18]Fiscal year ending July 31, 1960
[19]Canada only
[21]As of May 31, 1959
[23]Other Western Hemisphere
[24]Acquired by Delhi-Taylor
[25]Fiscal year ending April 30, 1960
[26]Fiscal year ending June 30, 1960
[27]Fiscal year ending August 31, 1961
[28]Fiscal year ending Sept. 30, 1960
[29]Fiscal year ending May 31, 1960

MORE PROFIT WITH AMMONIA



Kellogg Steam Methane Reforming Process Sets New Lows in Direct Operating Costs

Wherever you may be planning a new ammonia plant—for ammonia alone or as a component of a complete fertilizer complex, recent developments in Kellogg Steam Reforming now make a Kellogg-designed ammonia plant more economical than ever to operate as well as to build.

The figures shown above are direct operating costs per ton for five major U.S. areas. They are based on rates given in the utility table (right). Catalyst and chemical consumption have been included—at 34¢ per ton of ammonia product and 7¢ per ton, respectively. Labor, maintenance, taxes, insurance, depreciation and interest have not been included since these vary with individual client situations.

Feedstock for the process in this case is natural gas. Comparable low operating costs are possible with refinery gas feed, or even naphtha, under certain circumstances.

For a detailed description of Kellogg's ammonia process and other data, write for the new 12-page booklet—"Ammonia".

UTILITY UNIT COSTS*

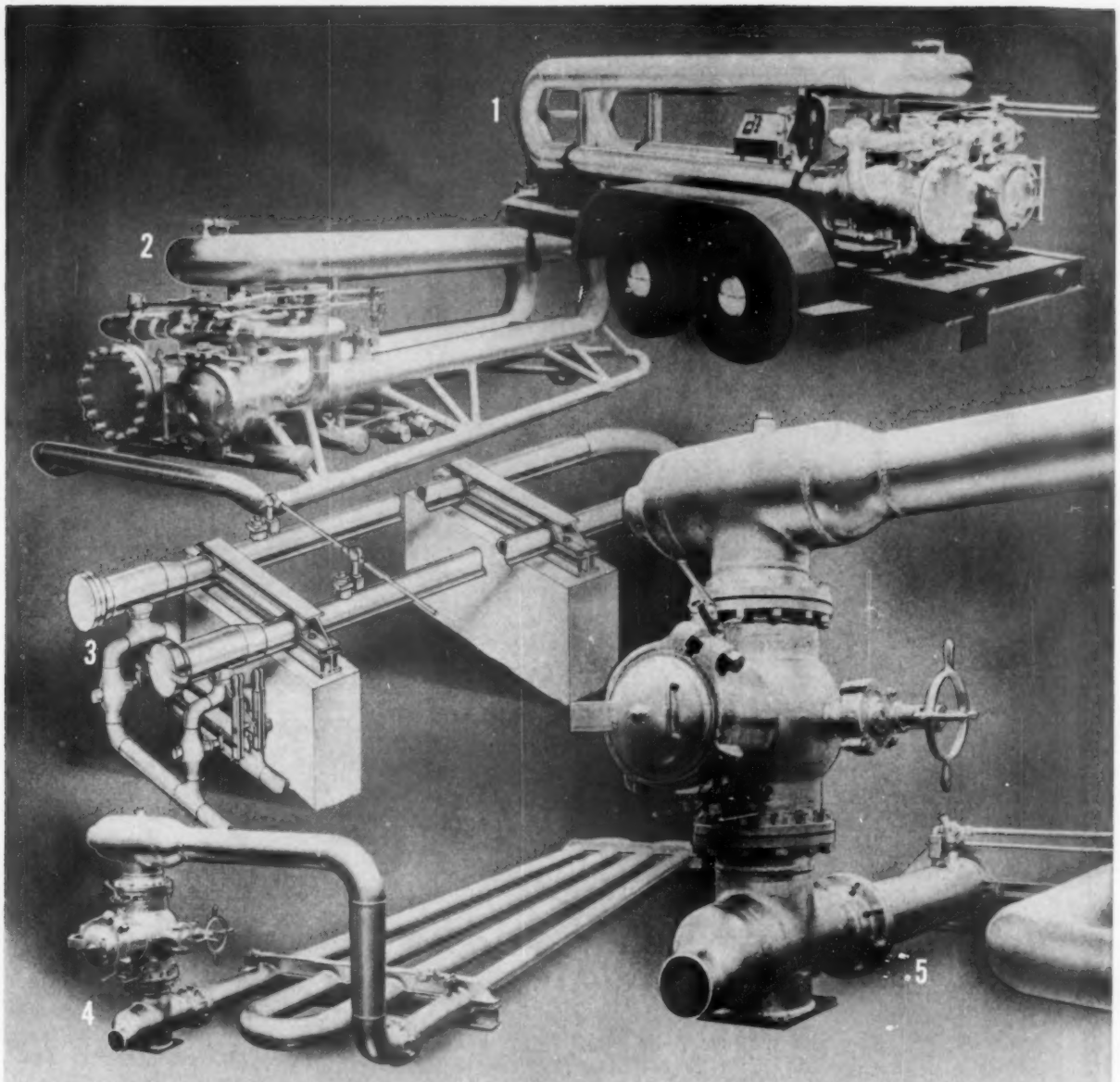
	EAST COAST	GULF COAST	MID-WEST	PACIFIC NORTHWEST	WEST COAST
Natural Gas—Feedstock and Fuel, ¢/MM Btu	59	20	40	38	37
Electric Power, ¢/KWH	0.7	0.6	0.8	0.5	0.9
Cooling Water, ¢/M Gals.	2.4	1.8	2.5	2.2	2.2
Steam, ¢/M Lbs.	65	32	67	56	56

**Cost of steam is based on minimum fuel cost for each area*

THE M. W. KELLOGG COMPANY

711 Third Ave., New York 17. *A subsidiary of Pullman Incorporated*

Offices of other Kellogg companies are in Toronto, London, Paris, Rio de Janeiro, Caracas, Buenos Aires



NOW ACCURATE, DEPENDABLE METER PROVING — Maloney's new precision built provers now make perfected meter proving practical on virtually all liquid-carrying lines. Constructed of high quality materials, Maloney unidirectional and bi-directional provers are fabricated under constant engineering supervision. Illustrated units are:

1. **Bi-directional trailer-mounted**
2. **Bi-directional skid-mounted**
3. **Bi-directional U-Bend**
4. **Unidirectional, interchange and loop**
5. **Unidirectional, interchange only**

The units illustrated are standard models. However, larger units may be specially engineered to fit a customer's particular need. For additional information on all Maloney meter provers, please write the Company's Houston office for Bulletins MP-1 and MP-2.

"Since 1932: Precision in Rubber—Metals—Plastics"

F. H. MALONEY COMPANY

P. O. BOX 1777 / HOUSTON, TEXAS

OFFICES IN LOS ANGELES • PITTSBURGH • TULSA

F. H. Maloney COMPANY

Improve your Engineering I.Q.*

* INCOME QUOTIENT

New-Product Development Vital to Industry: High Mortality Rate On Ideas, But Odds Can Be Reversed

Industrial "fairy tales" are few and far between, but here's one with more than a grain of truth. The situation, as you will recognize, has been duplicated frequently.

Before embarking on the short tale, it must be acknowledged that most companies cannot survive without new products or services for their various "publics." At this very moment, in all phases of industry, there are declining products. There are manpower and production facilities that must be utilized more profitably. *And it is to the engineers of today that industry looks for the new products and services of the future.* The road to successful new-product development, has many hazards and pitfalls and insists on a realistic appraisal of *all* phases of development. Perhaps the following "tale" is oversimplified, but it serves at least to introduce the subject for closer inspection.

Once upon a time, a sharp young man named Eddie Engineer had a whopper of an idea. He thought to himself: "If I can design this Widgit, I'll bet lots of people would be glad to pay $1 for it." After an infinite number of calculations and endless days, he finished his design.

But, Eddie Engineer was a *thinker,* not a *maker,* so he had to find someone to manufacture the Widgit. He found the best manufacturer in his locality, a man of good reputation named Freddie Fabricator. He showed Freddie his plans and convinced him that people would easily pay $1 for a Widgit. Freddie wanted to join in the enterprise, but he had to admit, "I suppose they would pay $1 for it, but it will cost at least $2 to make one of these Widgits, even on a volume basis."

So, poor, dejected Eddie had learned an expensive lesson, because all of his time and effort had gone for naught. If his time had been dollars, he'd have been broke.

Not long after, he had another whopper of an idea, this time for a Gidgit. Before he sharpened a pencil, however, he went over to see Freddie. Freddie said he could make the Gidgit and they both thought people would pay $2 for one. That way, they could both pocket enough to get rich.

WRITE FOR YOUR COPY TODAY
BOOKLET E-11
Improve your Engineering I.Q.*
NEW-PRODUCT DEVELOPMENT:
VITAL TO INDUSTRY
One of a Series, published by ... Heat Exchanger Division, WESTERN SUPPLY CO. TULSA, OKLAHOMA

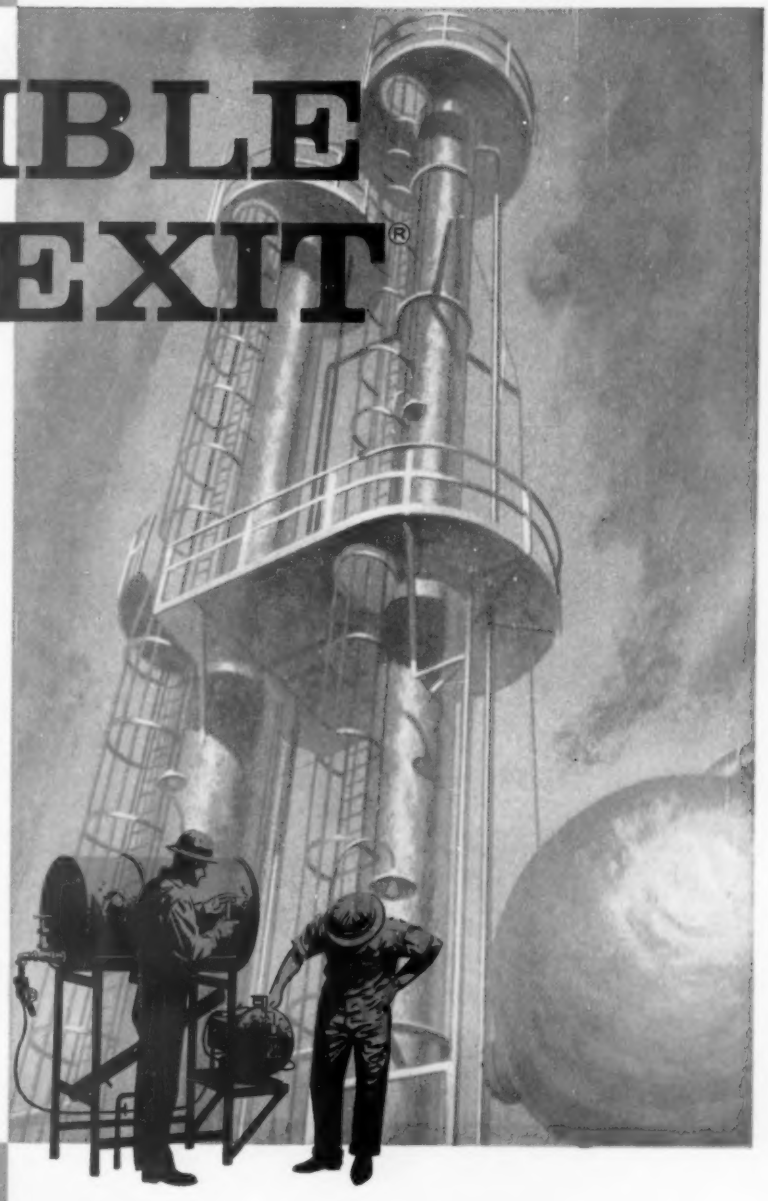
The climax to the "fairy tale" started in the foregoing paragraphs may be significant to the professional advancement of the creative-minded engineer who may make new-product design and development his next achievement. The road ahead for him may be difficult, filled with detours and dead ends, but its rewards can be worthwhile, both to the individual and his company.

In designing and producing heat transfer equipment suitable to our customers' needs, Western stays alert to the innovations and new developments demanded by continuous flow processes. We invite you to discuss your heat transfer problems — new or old — with members of our Heat Exchanger Division. Meanwhile, your copy of "New-Product Development" awaits your request.

WESTERN
HEAT EXCHANGERS
WESTERN SUPPLY COMPANY
P.O. Box 1888 – Tulsa, Oklahoma

98% protection* against internal corrosion

HUMBLE COREXIT®



* *Ten years of measurements* in refineries and gas plants prove its high efficiency and economy. For as little as 50¢ per thousand barrels of throughput, Humble COREXIT prevents internal corrosion in pipe still overhead, distillation towers, vapor recovery systems and other refining units. Equipment life is extended, you make longer runs between turn-arounds, and down time is reduced. *COREXIT makes important savings in every refinery and gas plant where it is used.* For complete information on technical services and COREXIT formulations to meet your specific requirements, see your Humble salesman or contact Humble Oil & Refining Company, Houston, Texas.

ENCO PRODUCTS

HUMBLE OIL & REFINING CO.

America's Leading ENergy COmpany

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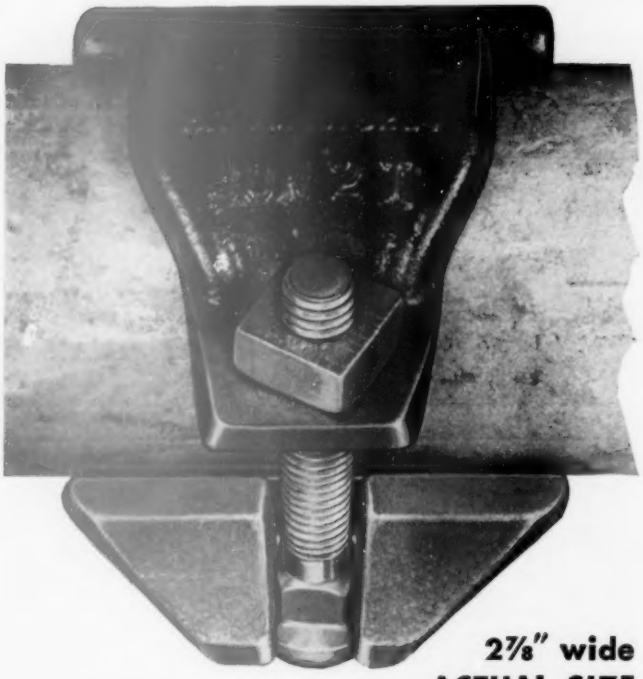
For speediest repair of corrosion leaks in pipe

JUNIOR EMERGENCY PIPE CLAMP



2⅞" wide
ACTUAL SIZE

Speediest application — slotted lug permits the single plated bolt to slide instantly into place.

A companion to the old reliable Emergency Pipe Clamp that has served industry for a half century, the JUNIOR, a single bolt clamp, is 2⅞" wide. Undersells most band-type clamps.

Made of malleable iron, ruggedly proportioned, with full length hinge along one side. Formed to exact pipe size. The recessed pressure-equalizing gasket, entire width of clamp, is "bonded" in place with plastic laminate adhesive. A lasting installation. Write for folder.

Lug on gasket half is slotted

M. B. SKINNER CO., South Bend, Ind.

SKINNER-SEAL JUNIOR EMERGENCY PIPE CLAMP

These are the men who REDUCE YOUR COSTS

D. M. Lawrence
General Service Mgr.
Pampa, Texas

Raymond Johnson
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Tommy Knobloch
Great Bend,
Kansas

Louis Sears
Odessa,
Texas

Harold Brown
Casper,
Wyoming

Enid Duggins
Houston,
Texas

H. B. Smith
Edmonton,
Canada

Jim Morrow
Seminole,
Oklahoma

Dave Kelley
Anaco,
Venezuela

D. C. Jordan
Tulsa,
Oklahoma

Minute-men are factory trained service men.

Interested in your service requirements.

Needless parts and repairs are eliminated because of their past service experience.

Unnecessary shut down time eliminated.

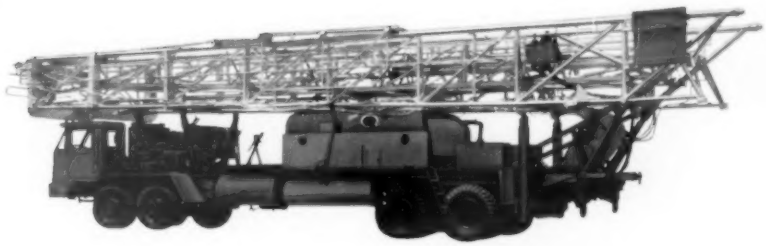
Trained service men don't guess — they know.

Efficient controlled steps reduce your service costs.

Maintenance requirements reduced by minute-men servicing.

Economical service because minute-men are economy minded.

Net profits protected because properly serviced units have a longer life.



Use First Class Service
for First Class Servicing Units

WELL SERVICING AND DRILLING UNITS
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PAMPA, TEXAS
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CABOT CORPORATION
MACHINERY DIVISION

Brass Tacks

FROM HALLIBURTON

FRACTURING TREATMENTS

Bring Better Results Than Operators Thought Possible

Acidfrac makes good gas well from non-producer

Barber County, Kansas — Acidfrac switched this apparent non-producer into a 12,800,000 cu. ft./day gas well. The operator nearly plugged the well, but decided to try stimulation first. A 500 gal. treatment of Halliburton MCA (mud cleanout agent) upped production to 500,000 cu. ft./day. Encouraged, the operator followed with a 25,000 gal. 7½% Acidfrac treatment at 3,000 psi with 20,000 lb. of 20-40 and 10,000 lb. of 10-20 round sand. Result: a profitable producer making 12,800,000 cu. ft./day.

A "Dry" Hole until Sandoil treatment turned it to 480 BOPD Producer

Sweetwater County, Wyoming—Halliburton used an unusually high rate and volume when fracturing this apparent dry hole with the Sandoil technique.

Although Electric Log and Drill Stem Test were disappointing, a producing well a mile away influenced the operator to set casing. Perforations were made between 3,336 and 3,665 feet in the Mesa Verde sand. Statistics: two Halliburton HT-400 trucks, 36,000 gal. No. 2 diesel oil with one gal. Halliburton Hyflo per 1,000 gal. oil, 1/20 lb./gal. FL-2 low fluid loss additive, plus 28,800 lbs. sand propping agent. Results: 400 BOPD initial production on 24/64" choke, still flowing 170 BOPD four months after treatment.

Vis-O-Frac brings in well for 120 BOPD

Walthall County, Miss. — This Vis-O-Frac treatment broke through an apparent permeability barrier at 9,676 ft. A 500 gal. volume of MCA led the treatment which consisted of 20,000 gal. Vis-O-Frac (gelled light petroleum fluid) with 25,000 lbs. 20-40 sand. Production immediately after treatment was 120 BOPD which improved to 148 BOPD after four months.

Multi-stage Fracplan Turns Non-Producer into 2½ million cu. ft./day well

Walthall County, Miss. — Another operator in this area accepted Halliburton's recommended Fracplan to improve gas production from 9,606 to 9,628 section of the Tuscaloosa sand. A three stage Waterfrac job was performed using Perfpac balls as the Multifrac diverting agent. Each stage consisted of a 3,170 gal. pad volume followed by 7,200 gal. gelled lease salt water with WAC-8 low fluid loss additive . . . carrying 3,170 lbs. 20-40 sand and 550 lbs. 12-16 aluminum pellets. A month after treatment, the "non-productive" well was making 2.5 to 3 million cu. ft./day and 7 bbl. condensate/mmcf at 2,100 psi with further improvement expected to outperform offsets.

See your Halliburton man for the latest developments in formation fracturing. Ask him about the many techniques he can supply to help improve production from your wells . . . including Fracplan and the Fracometer — two new partners in progress from Halliburton.

First and Foremost in Formation Fracturing

FRACTURING SERVICES

Halliburton
COMPANY • DUNCAN, OKLAHOMA

Things To Come

DEEPER DRILLING

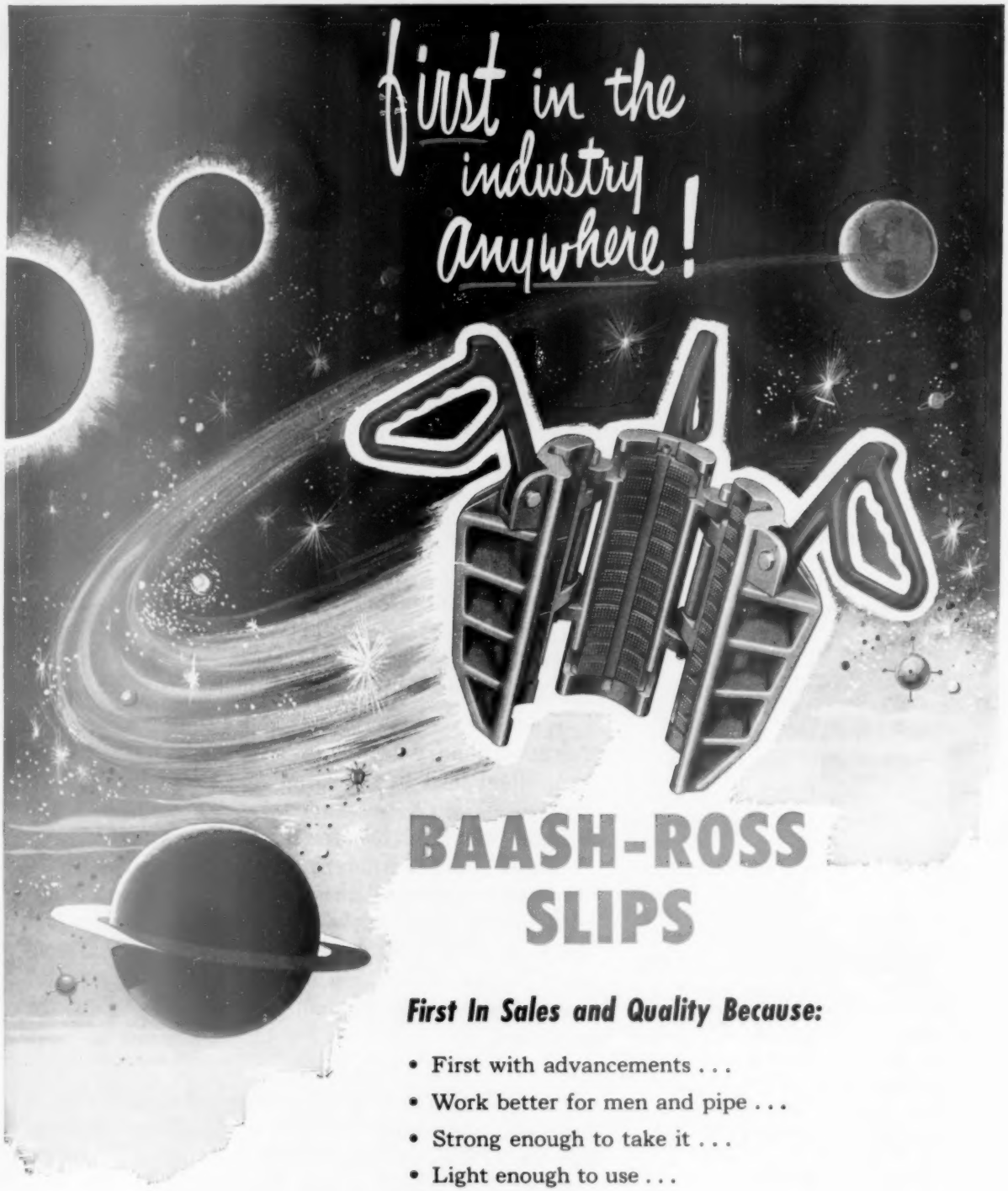
1961 may set a record for deep drilling . . . worldwide. U. S. wells below 15,000 ft have increased steadily in past five years (143 in 1960) and will set a new high this year. Deep trend in Oklahoma booming with one well projected to 20,000 ft. Atlantic continues to drill ultra deep producers in West Texas. No slow down in deep wells in South Louisiana where Mecom drills ahead below 20,000 ft. Big rigs in Alaska push holes below 11,000 ft. Delta has giant rig in Australia capable of going to 25,000 ft. Completed one to 13,500 ft. Canada completed its deepest well to 16,500 ft. Kerr-McGee is building biggest offshore mobile barge afloat capable of ultra deep wells. Deeper drilling in 1961 should keep total footage drilled at last year's level.

NEW HEAT SOURCE

A revolutionary heating source using natural gas to produce heat in the range of 3000 to 6000 F has been developed by Arthur D. Little, Inc. in its Cambridge, Mass., laboratories. The process uses a "boosted" burner whereby electrical energy is superimposed on energy derived from combustion of natural gas or other fuels. In a demonstration before AGA members for whom the program was conducted, tantalum, one of the "hardest-to-melt" metals, went limp at 5400 F when subject to the new heat.

CEMENTING HOT WELLS

Twenty-five to 35 lb of silica flour per sack of cement will solve the problem of cementing casing in ultra-hot wells. The patented additive is a finely-ground (minus 200 mesh) silica looking much like face powder. Halliburton researchers found that the material exhibits relatively high compressive strengths and is compatible with other cement additives. Most significant use was in a steam well drilled in the Salton Sea area to 5000 ft where bottom-hole temperatures reached 700 F. Casing was cemented without trouble. This temperature is about the same as that expected in a 50,000-ft hole and much higher than ever experienced before.



BAASH-ROSS SLIPS

First In Sales and Quality Because:

- First with advancements . . .
- Work better for men and pipe . . .
- Strong enough to take it . . .
- Light enough to use . . .

"Matched Tools for Unmatched Performance"

OUR 42d YEAR OF PROGRESS

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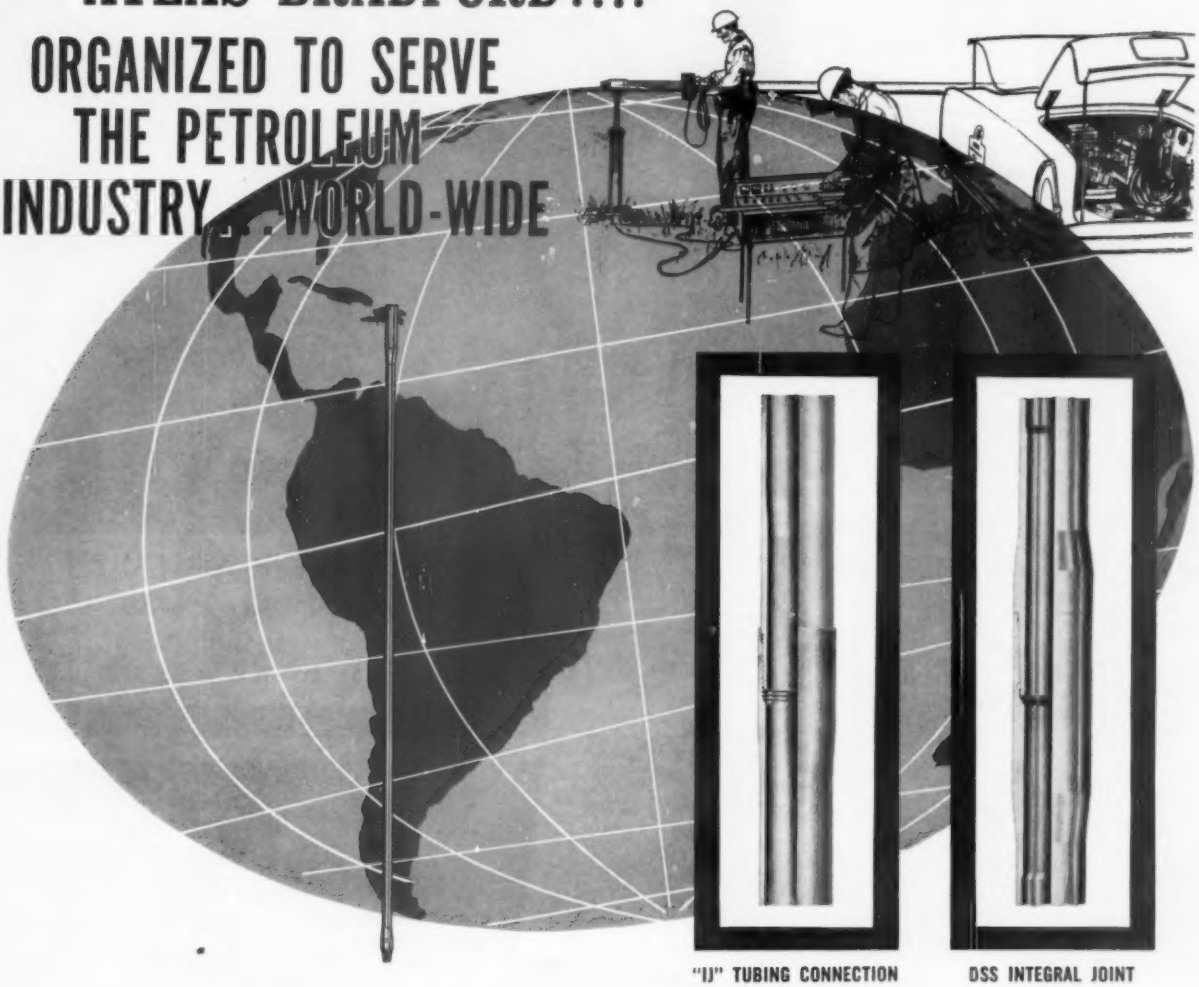
ATLAS BRADFORD....

ORGANIZED TO SERVE THE PETROLEUM INDUSTRY...WORLD-WIDE



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Manufacturer and Supplier to Drilling, Production, Refining, including Tubular Goods and Inspections

Equipment and supplies for use in all phases of the industry . . . from drilling to refining in all parts of the world . . . can be furnished by Atlas Bradford Company.

Tubular goods and services, including the economical Atlas Compact "IJ" tubing connection, the H-G specialized connections and the UNISCO Tru-Tech-Tron inspection of used drill pipe and tubing, have all been combined under the Atlas Bradford Company name for better service in every area.

Interchangeable with API 10 Rd. thread non-upset T & C tubing, "IJ" has a recessed box; joint efficiency above calculated theoretical; full bore; a design permitting "burying" the last thread; and manufactured to conform to applicable parts of API 5A standards. All this at reduced costs!

The DS and DSS joints (Pat. Pending), feature the Teflon* tight seal for maximum clearance in multiple completions with high efficiency, high pressure connections. More than 3,000,000 ft. in use!

Tru-Tech-Tron is the most advanced method of electromagnetic inspection of tubular goods for absolute evaluation of pipe condition.

For efficiency and economy on equipment, supplies, and service in petroleum industry operations everywhere . . . look to Atlas Bradford Company.

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"A great step forward with your Planetary Gears, Big Bearings and Cylindrical Crossheads."

— J. K. Butler

OIL PRODUCTION MAINTENANCE, INC.
7440 CHOCOLATE BAYOU ROAD -- P. O. BOX 14291
HOUSTON 21, TEXAS
August 31, 1960

Mr. Gordon P. Street, President
The Wheland Company
Chattanooga, Tennessee

Dear Mr. Street:

Our Wheland Planetary Pump is giving us increased penetration and good savings on bits. We know from more than 18 months of constant operation on 10,000 Ft. wells that our savings are substantial.

We have kept an accurate record on operating costs and all maintenance costs and are especially impressed by the low cost of fluid end expendables. The HP-16000 Pump has constantly operated near its rated capacity on more than 200,000 feet of hole in the Texas Gulf Coast Area.

We are now operating Wheland HP-18000, HP-14000, and HP-16000 Pumps and are glad to recommend them. Your new HP-16000 Pump design is a great step forward with your planetary gears, big bearings and cylindrical crossheads.

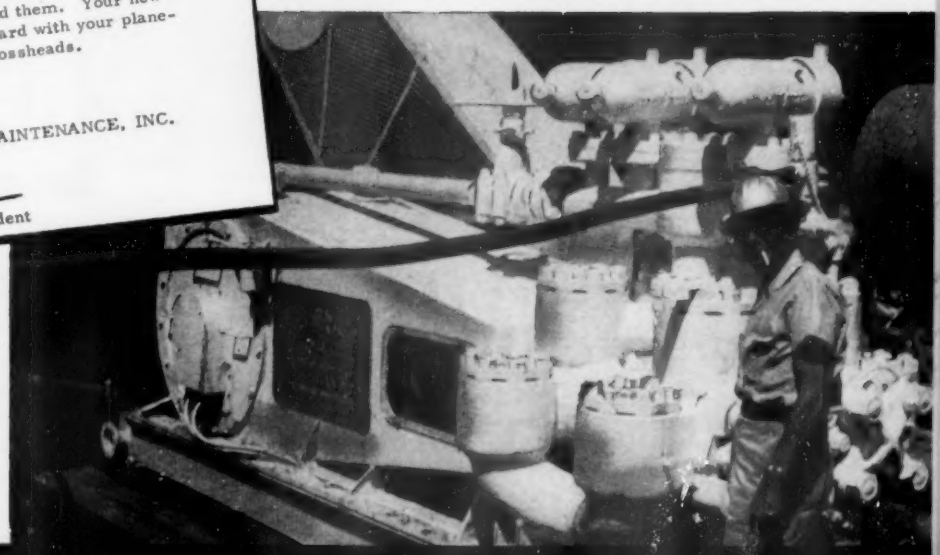
Yours very truly,

OIL PRODUCTION MAINTENANCE, INC.

J. K. Butler

J. K. Butler, President

WHELAND PLANETARY
HP-16000 PUMP
Duplex Power Slush Pump
7¾" x 16", 600 H.P. at 65 RPM



Wheland HP-16000 Planetary Pump owned by Oil Production Maintenance, Inc., on location in the Gulf Coast area.

WHELAND

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THE WHELAND COMPANY
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DRAW WORKS • SLUSH PUMPS • ROTARIES
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3 outstanding CAMCO tools for reliable flow channels between tubing and casing annulus

These three outstanding tools from Camco provide flow channels between the tubing and the casing annulus which can be readily opened and closed as required. Choose the one which best suits your requirements, for circulating, spotting acid, fracturing, producing or killing the well. You'll simplify and help to insure the success of the operation by the installation in your tubing strings of

Dependable-Shifting
Positive-Sealing

CAMCO SLIDING SLEEVES

The three Camco Sliding Sleeves incorporate the same basic sleeve design, as shown in the illustration. This design features:

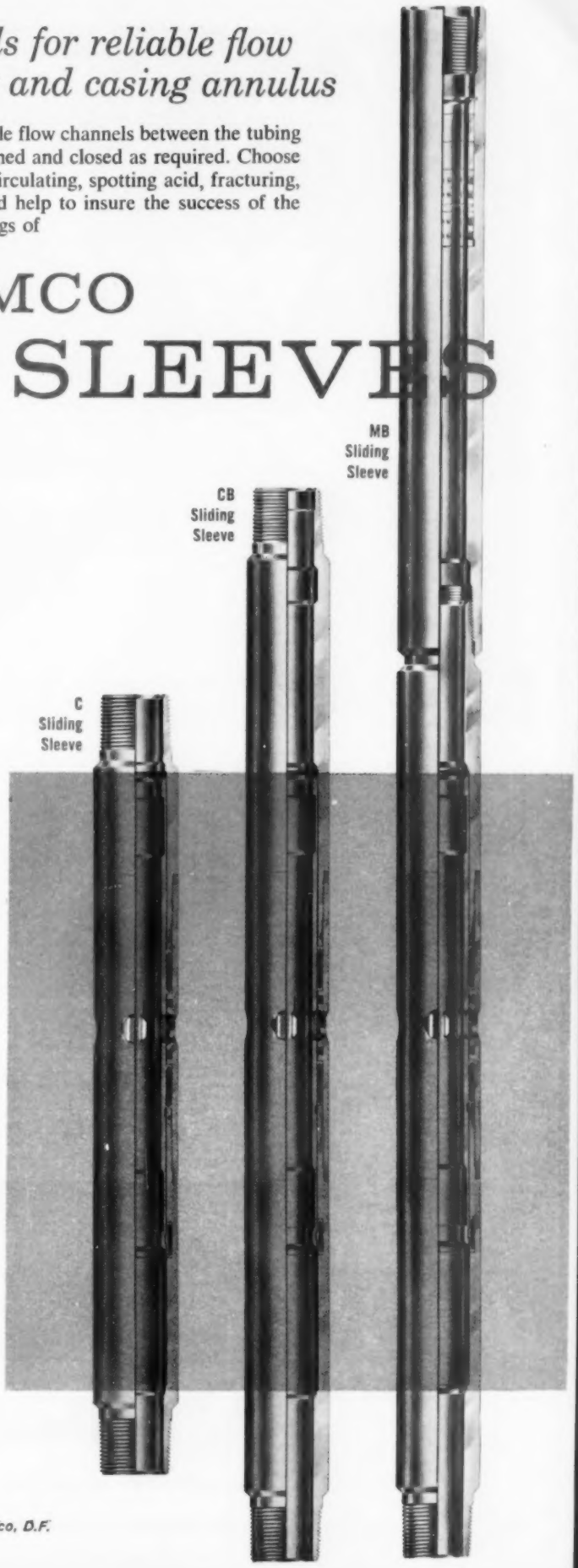
- Collar O.D. and essentially full-opening tubing I.D.—ideal for multiple completions.
- Low-friction, high-pressure seals, permitting shifting virtually unaffected by temperature or pressure.
- Relief slots to equalize pressures before opening completely.
- Tensile strength greater than that of P-105 tubing.

The **C** Sliding Sleeve has proved itself ideal for every **normal Sliding Sleeve application.** In one typical demonstration of its reliable operation under severe conditions, a Camco C Sleeve at a depth of 7615 feet in a Wyoming well was opened and closed without difficulty in 12.6 pound mud. Any number of C Sleeves can be installed in the tubing, and operated selectively with commonly used shifting tools.

The **CB** Sliding Sleeve, a combination of the C Sleeve with a Camco D Landing Nipple, is equipped to **receive and pack off a Camco C Lock** with any of various production tools attached. The simple, non-selective CB Sleeve is the ideal choice for a single-sleeve installation.

The **MB** Sliding Sleeve provides **complete selectivity** and unequalled versatility by combining the C Sleeve with the electronic Magnaset Nipple. MB Sleeves can be selectively opened and closed, and a **Magnaset Lock** with affixed production tool can be **selectively placed, locked and packed off** in any MB Sleeve.

C, CB, or MB? One of these Camco Sliding Sleeves is right for your application. Get full information from your Camco representative, or write



CAMCO

"PRODUCING PETROLEUM PROGRESS"

CAMCO, INCORPORATED
Box 14484, Houston 21, Texas

CAMCO, LIMITED, Belfast, U.K. - CAMCO DE MEXICO, S.A., Mexico, D.F.

A superior thru-tubing jet perforator featuring:

ENCLOSED FIRING SYSTEM

MINIMUM DEBRIS

DEEP, CARROT-FREE PENETRATION

HIGH WELL FLOW INDEX

The McCullough Mac-Jet is an all-new development in expendable jet perforating – designed to provide maximum perforating efficiency – to obtain highest production from thru-tubing and slim hole completions.

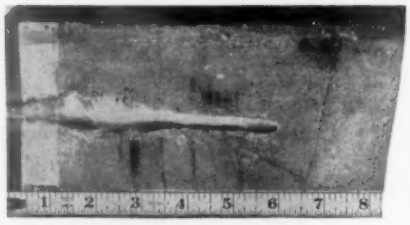
- Enclosed Firing System – Each Mac-Jet unit is self-contained, including jet charge and integrated firing system, enclosed in a frangible, high strength case This design eliminates the use of exposed primacord. Units are securely locked together and may be fired from bottom up or from top down.
- Minimum Debris – Entire Mac-Jet Perforator breaks up into small bits when fired. Mac-Jet units, spacers and bottom firing assembly are all disintegrating to assure complete break-up.
- Superior Perforation Characteristics – "big gun" performance – penetration equal to or better than that of many larger jet casing guns. Carrot-free perforations, large deep holes, high well flow index.
- Size, Shot Density, Length – 1 11/16" OD and 2 1/16" OD Standard shot density is four per foot, 90° phasing.

ALL NEW McCULLOUGH *mac-jet*

Disintegrating spacers are supplied to provide fewer shots per foot when required. Any number of Mac-Jet units may be run in any length desired.

SPECIFICATIONS:

	1 11/16" OD	2 1/16" OD
Pressure, Temperature Rating	15,000 psi. @ 300°	13,500 psi. @ 300°
Maximum Temperature	350°	350°
Total Charge Weight	12 grams	20 grams
Av. Penetration (Berea Sandstone)	5.69"	7.45"
Av. Entrance Hole	13/32"	7/16"
Av. Well Flow Index	1.1+	1.44
Fill-up – 1' Gun, 5½" Casing	1"	–
Fill-up – 1' Gun, 7" Casing	½"	1"



Standard Berea Sandstone target perforated by 1 11/16" OD Mac-Jet Average penetration, 5.69"; average entrance hole size, 13/32; average well flow index, 1.1+

DISINTEGRATING SPACER – Available in various lengths to provide fewer than four shots per foot. Disintegrates into small bits when perforator is fired

McCullough *TOOL COMPANY*

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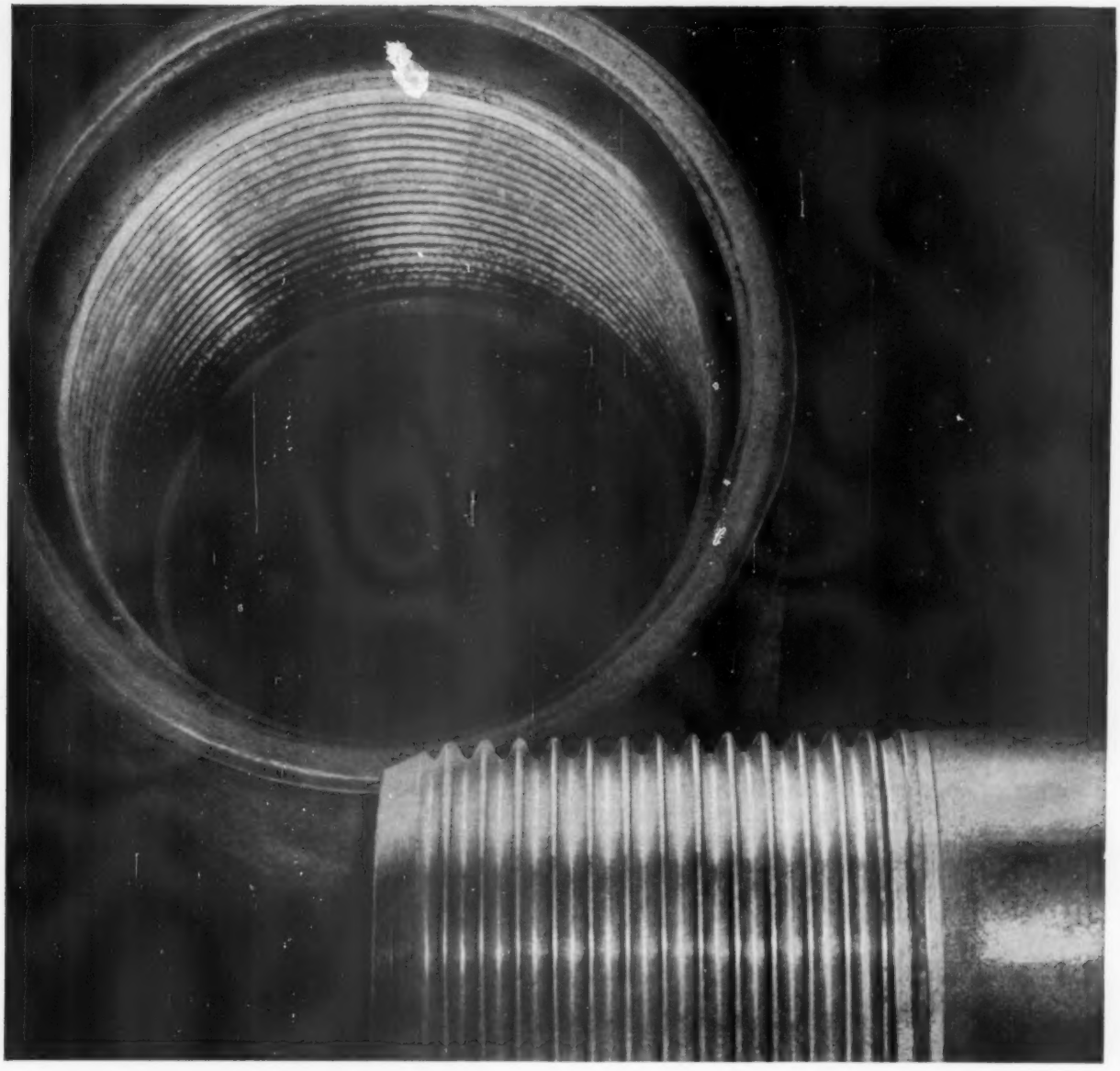

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There's not a weak link in the lot. Every thread has the right lead, taper, height and size. The result is seamless tubing and casing that has *extra* strength and is pressure tight where it needs it most—at the critical area of the threaded connection.

CF&I Oil Country Casing and Tubing meet API STD 5A specification and are available in sizes from 2⅜" to 9⅝" O. D. Contact your nearby CF&I sales office or distributor for speedy delivery.

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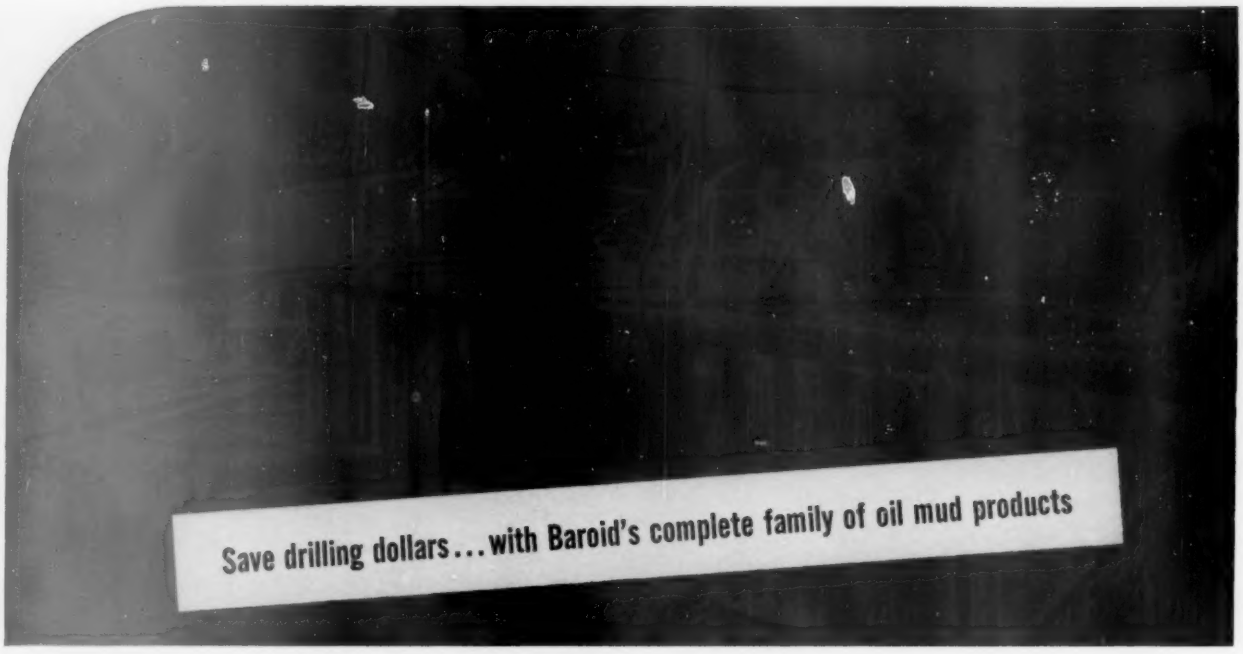


BAROID OIL MUD SOLVES DEEP

Baroid Field Report: Terrebonne Parish, Louisiana. This case history exemplifies the use

MUD PROBLEM:

To maintain an oil mud having good filtration and flow properties while drilling a 5¾ inch hole with 18 ppg mud at depths to 16,500 feet

WELL DATA

LOCATION: Hollywood Field, Terrebonne Parish, Louisiana
TOTAL DEPTH: 16,570'
BOTTOM HOLE TEMPERATURE: 275 to 300 F

CASING PROGRAM

SIZE, INCHES OD	DEPTH SET, FEET
13⅜	3,499
9⅝	13,490
7	14,328
4½	16,570 (liner)

MUD ADDITIVE PROGRAM

0' to 3,499'	Native mud, water and AQUAGEL*
3,499' to 8,880'	AQUAGEL—caustic soda—Q-BROXIN**
8,880' to 15,100'	Emulsion mud with Gypsum — Q-BROXIN, BAROID*, DMS† and TRIMULSO*
15,100' to 16,570'	Baroid Oil Mud containing INVERMUL*, DURATONE†† and PETROTONE*

TYPICAL MUD PROPERTIES OF THIS BAROID OIL MUD

Depth, ft	15,100	15,487	15,978	16,380	16,521
Weight, ppg	17.5	17.7	17.7	17.7	18.0
Viscosity, sec	74	94	98	104	92
Initial gel, g	2	0	10	10	8
10 minute gel, g	15	12	18	20	18
Filtrate, API, ml	0.0	0.0	0.0	0.0	0.0
Filtrate, 275 F, 500 psi, ml	3.0	4.8	5.2	5.4	4.8
Average Sp Gr, Solids	4.2	4.1	4.1	4.2	4.2
Oil/water, % by volume	47/16	46/17	46/16	45/16	46/15

DISCUSSION: Tight-hole conditions had been experienced while drilling to 15,000 feet in this Terrebonne Parish, Louisiana well. A 7 inch liner to be set (in 8¾ inch hole) at 15,000 feet was stuck at 14,327 feet. Three conditions had to be considered while reaming and drilling to projected total depth: (1) drilling about 1,500 feet of 5¾ inch hole with 18 ppg mud; (2) possibility of differential sticking of drill pipe; (3) extremely small clearances if a 4½ inch liner was to be set at total depth.

SOLUTION: Baroid Oil Mud containing INVERMUL emulsifier, DURATONE filtration control agent and PETROTONE suspending agent was selected to drill the bottom 1,470 feet of hole. This Baroid Oil Mud was used because of excellent control properties (API filtration held at zero, filtration at anticipated BHT of 275 F to 300 F could be easily controlled, flow properties compared to those of water-base muds), and because maximum hole stability and lubrication would be attained.

At 14,327 feet the water mud was displaced with approximately 1,500 barrels of pre-mixed 17.5 ppg Baroid Oil Mud. The 7 inch liner was cemented, cement was drilled, and reaming to bottom was begun. While reaming to bottom, the water mud in the hole (about 5% of total volume) was incorporated into the Baroid Oil Mud with no difficulty.

The 5¾ inch hole was drilled from 15,100 to 16,570 feet at about the same penetration rates normally attained with water muds. Maintenance of the Baroid Oil Mud consisted of periodic additions of diesel oil, INVERMUL emulsifier and DURATONE filtration control agent. A 4½ inch liner was successfully set at total depth.

*AQUAGEL, bentonite; BAROID, weight material; TRIMULSO, surfactant; INVERMUL, emulsifier; PETROTONE, suspending agent; DRILOIL, oil mud concentrate; and DRILTREAT, stabilizer; are Registered Trademarks of Baroid Division National Lead Company.
**Registered Trademark, Puget Sound Pulp and Timber Company.
†Registered Trademark, Socony Mobil Oil Co., Inc.
††DURATONE, filtration stabilizer, is a Trademark of Baroid Division National Lead Company.

BAROID—*Still Pioneering Drilling Mud Research • Engineering • Marketing*

DRILLING PROBLEM (BHT 300 F)

of one type of Baroid Oil Mud to solve this particular problem.

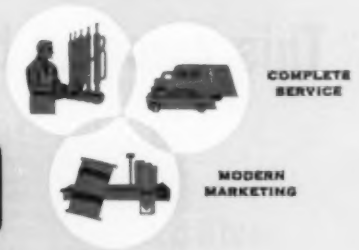
The Baroid family of oil mud products allows the operator to select an oil mud having the properties suitable for his particular drilling problem. This approach has long been used in the selection and treatment of conventional water muds but is new to oil muds. These oil mud properties can be modified by treatment with INVERMUL, DURATONE, PETROTONE, DRILOIL* and DRILTREAT*. Baroid's new approach to oil muds has resulted in their successful use for drilling, coring, completion, perforating, gravel packing, packer fluids, freeing stuck drill pipe, and for fishing.

In this case history in Terrebonne Parish, Louisiana, a Baroid Oil Mud was selected as the practical solution to the problem of drilling a 5¾ inch hole at depths to 16,500 feet and temperatures to 300 F. At 15,100 feet an INVERMUL-DURATONE-PETROTONE Oil Mud was used to displace the water mud. Periodic additions maintained the excellent filtration and flow properties of the oil mud. Drilling was trouble-free and completion successful at 16,570 feet.

INVERMUL, a free-flowing powder, the basic ingredient in this Baroid Oil Mud is an active, readily oil-dispersible emulsifier that stabilizes the emulsion and protects productive formations by controlling filtration.

PETROTONE is a dry powdered colloid that imparts solids-suspending properties to all types of oil muds and is easily mixed. The usual amount added is from 1 to 5 ppb of oil mud. PETROTONE is stable at the highest bottom-hole temperatures presently encountered in drilling.

DURATONE, a unique organic colloid, controls filtration of all types of oil muds at the highest bottom-hole temperatures. The development of DURATONE and PETROTONE as companion products to INVERMUL has diversified and extended the application of oil muds. This is another example of how Baroid's customer-oriented program of research and engineering saves you drilling and completion dollars and keeps your operations on schedule.



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National Tube uses two other carbide-tooled machines in this threading line—a profiler that

cleans the cutting surface, and a facer that end-faces, bevels and reams out the pipe. All three machines are linked into one continuous operation to produce perfect threads.

Carbide threading is only one of the many "extras" that National Tube uses to produce high quality seamless oil country tubing. Consider USS National Tubing for your next tubing installation.

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Grove Seal-"O"-Ring® Valv-Pak combines the compactness and light weight of an integral Christmas Tree valve assembly with the flexibility of a conventional wellhead manifold that permits any single component to be changed without replacing the complete unit.

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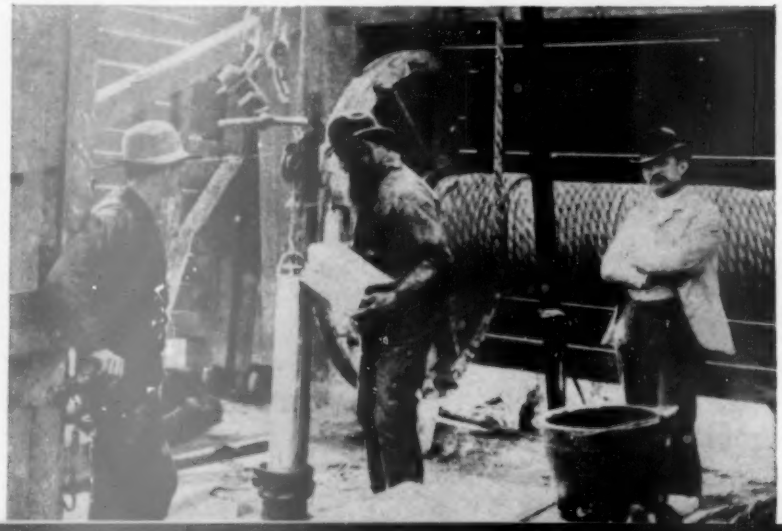
First joint of Pittsburgh Steel casing is ready to enter hole drilled near the 1907 scene pictured below.

THE ROUGHNECKS WORE DERBIES

Roughnecks casually pour nitro into well preparatory to shooting in the early Bradford field in Pennsylvania about 1907.



Pioneer Independent Distributor Now Sells Pittsburgh Steel Oil Country Goods From New York To Texas

Roughnecks wore derbies and horsepower had tails when one service-minded Pittsburgh Steel Co. independent distributor began operations in the pioneer Pennsylvania grade field.

Today, 54 years later, his flexibility, imagination and personal service still make the difference.

This typical "Mr. Independent" now provides oilmen in eight states with seamless tubular products

Roughneck cleans threads on Pittsburgh Steel seamless casing before running it into hole. Independent distributor who sold this casing has handled Pittsburgh Steel's tubular goods for nearly a quarter-century.

Inspecting joint ends are Peter E. Douylliez, Pittsburgh Steel Co. field engineer; Homer Ferringer, foreman for Manufacturers Light & Heat Co.; and Mark Wagner, salesman for distributor.

made by Pittsburgh Steel Co., a pioneer in its own right, whose experience with oil country goods goes back to almost the turn of the century.

• **From Soft Hats To Hard Hats**—As an early distributor whose history started in 1907, this Mr. Independent grew and flourished with the expanding industry and his stores followed the new fields across two-thirds of the continent.

Now he supplies oilmen in Texas, Oklahoma, Michigan, Pennsylvania, New York, Indiana, Kentucky and Illinois.

Three generations of the same family have run the business with the grandson of the founder now in the president's office.

With service and good products as a foundation, this distributor built up a wide range of shop facilities and repair equipment until now he is unique in the field. Nearly a quarter-century ago, he began supplying his customers with seamless tubular products made by Pittsburgh Steel Co., also a pioneer in its field. Let Mr. Independent tell you himself why these two veterans—an independent distributor and a mill that sells only through non-captive outlets—work together so well.

• **Lots Of Help**—"We get awfully rough competition from some of the big fellows. But we make out by being flexible, imaginative and by giving personal service.

"Pittsburgh Steel gives us a lot of help. The mill bends over backward to cut red tape and it moves fast when it's necessary to get some quick action."

You can't do better than making a connection with an independent Pittsburgh Steel distributor. His only obligation is to his customers.

For your next order of drill pipe, casing or oil well tubing, get in touch with one of the Pittsburgh Steel independent distributors listed below.

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Buckeye Supply Company Zanesville, Ohio	**Lucey Export Corporation** New York 7, New York	**Southwest Supply Company** Pittsburgh, Pennsylvania
C. W. Cotton Supply Company Tulsa 5, Oklahoma	**Lucey Products Corporation** Tulsa 19, Oklahoma	**The Straker Supply Company** Jackson, Michigan
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No charts. No tables. No guesses. You know you're cutting costs . . *not profits* . . with Broderick & Bascom cut-off plan.

Why not use a plan based on *average* rigs? Because no two rigs are strung up or operated alike, so critical rotary-line wear never occurs at the same points. For maximum rotary-line life each rig requires an *individual* cut-off plan based on its own equipment's dimensions. Your toolpusher can furnish these necessary measurements within 15 minutes. Then a Continental-Emsco/Broderick & Bascom team of specialists can engineer a cut-off plan . . the only one "tailored" *specifically* to your equipment. Many calculations? Accurate? *You bet!* But it's yours at *no extra cost* when you use Yellow Strand "POWERSTEEL."

With such a plan, indicating both *length* of cut-off and *when* to cut, many contractors report up to *30% longer rotary-line service!*

Next time you string up, you'll be dollars ahead talking to a Continental man about "POWERSTEEL" and an accurate rotary-line cut-off plan . . *measured and rated* . . to fit *one* rig . . your own!

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by R. J. Duran

How To Evaluate Mud Desanding

AN evaluation procedure to determine exactly how much money desanding saves has been worked out by Loffland Brothers Company engineers. The procedure was developed in a year-long program and proved out on a 12,000-ft well in Mississippi.

By applying this procedure, which also takes operational aspects into consideration, Loffland engineers calculated a total of $8112 was saved through use of a desander on the Mississippi well. The saving consisted of $6420 in mud materials and $1692 in water costs.

Desanding drilling fluid from top to bottom made it possible to carry less mud weight (from ½ to 1 lb per gal less) than offset wells. Hydraulics were improved, penetration rates were increased and the hole was maintained in good shape.

Here is the engineering approach to the problem:

Desander Sizing Important

It is just as important economically to match capacity of the desander with anticipated mud pump output as to match the rig with the well to be drilled.

A certain fraction of drilled solids removed from the hole pass through the shaker screen and particle size of this fraction is still relatively large. If these particles are allowed to recirculate back through the hole, they will be reduced to a finer size by the grinding action of the drill string and bit. Grinding and hydration tend to increase greatly the particle surface area. The net effect is an increase in viscosity.

A desander's ability to remove this finely divided fraction is greatly reduced, dilution becomes necessary and mud maintenance cost increases.

Mud pump discharge rates when drilling seldom exceed 500 gal per min past depths of 6000 ft. But from the surface to this depth, the rate may go as high as 800 to 1000 gal per min. Because penetration rates are high and volume of drilled solids is greater in the upper part of the hole, it is important to control solids in this section to a minimum.

An 8-in. cone desander has a rated capacity of 200 to 250 gal per min. A desander with four of these cones had the required capacity (800 to 1000 gal per min) to handle flow rates of the mud pump in the upper part of the hole. Later, as the hole deepened, mud pump capacities decreased and the solids became firmer, the de-

Table 1. Summary of Drilling Record and Desanding Performance on a 12,000-ft Mississippi Well.

Depth, ft	Average rate of penetration ft/hr	Lb solids drilled up per hr	Weight at underflow lb/gal	Volume of underflow bbl/hr	Lb removed by desander per hr	% of total solids removed by desander
1,500	82	8850	15.4	9.8	4860	55.0
5,100	40	4320	13.2	8.6	2920	67.5
6,500	48	5175	13.8	7.0	2700	52.0
8,400	16	1725	12.8	2.4	756	44.5
9,200	41	4420	13.9	4.8	1880	42.5
9,800	20	2160	14.8	2.5	1140	52.7
10,200	11	1190	14.8	1.3	590	49.5
10,500	20	2160	15.0	2.1	990	46.0
11,200	12	1295	14.7	1.4	650	50.0
11,600	16	1740	14.5	1.9	920	55.5
12,000	12	1295	15.1	1.6	764	59.0
					Average	52.0%

Comparison of solids removal from shale shaker at left with desander at right. Note difference in size of solids at center of photo from those at top of photo coming from desander.

sander could recycle (or re-desand) up to 50 to 80% of the circulated volume. This size desander would assure maximum desanding from the surface to total depth where native weight mud was to be used.

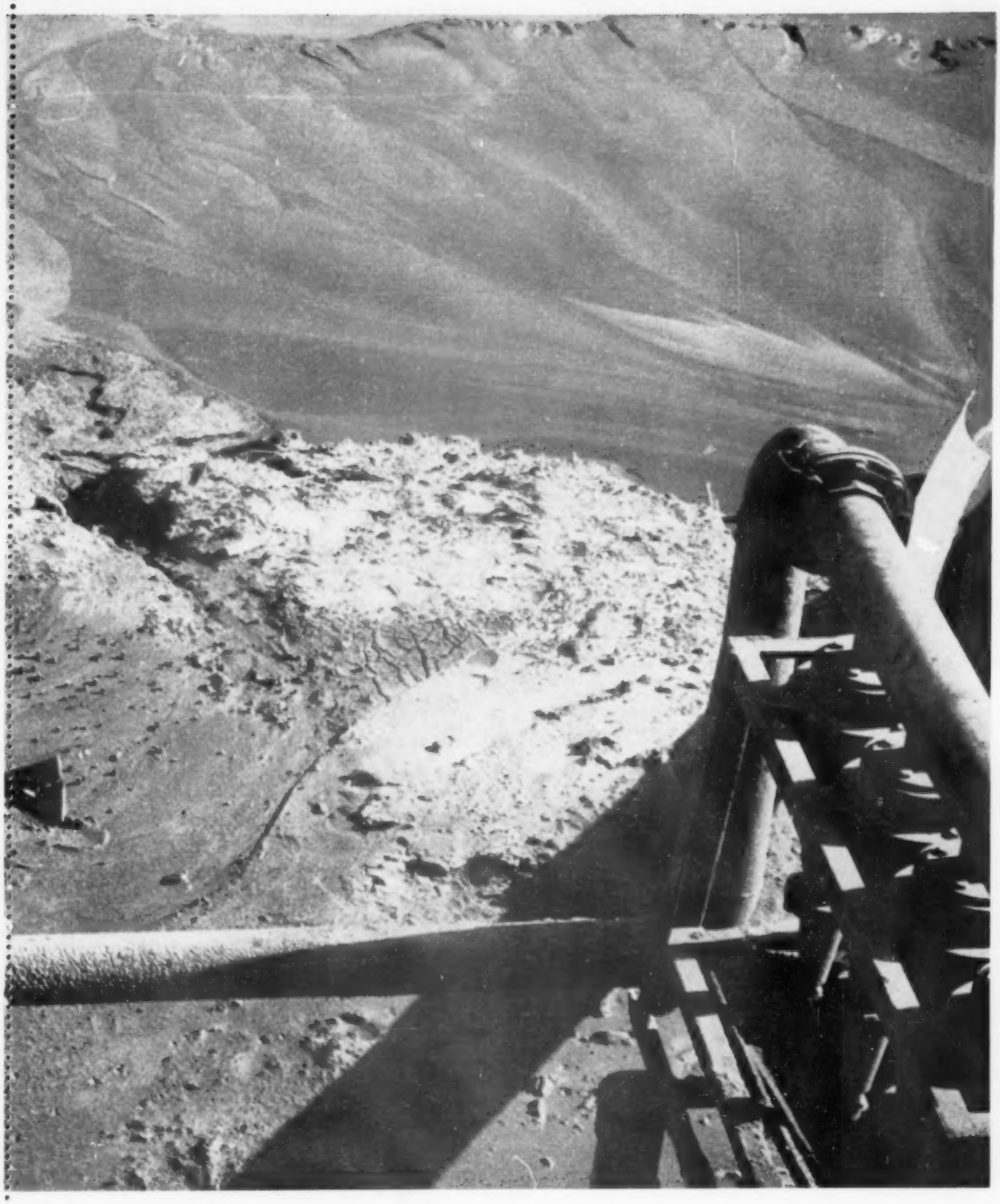
It was found that a centrifugal pump with an 11-in. impeller turning at 1400 to 1600 rpm would produce adequate flow rates at optimum discharge pressure of 45 to 55 psi. It was determined that it would take between 45 to 55 hp to drive the centrifugal pump.

Desanding Study of Mississippi Well

Detailed drilling fluid and desanding performance records were maintained throughout drilling the 12,000-ft well in Mississippi. These data are summarized on Table 1.

Formula:

$$P_s = \frac{70\ (W_o - W_w)\ (21.43)}{D^2 \times 0.85 \times R \times Q_s \times E_n}$$



Where:

P_s = Percent of drilled solids removed by desander.

W_o = Weight of underflow, lb per gal

W_w = Weight of water, lb per gal

D = Diameter of hole, in.

R = Drilling rate, ft per hr

Q = Volume of underflow, sec per qt

E = Percent of hole enlargement

21.43 = Constant

0.85 = Constant (based on 2.5 specific gravity solids)

Before the well was started, lithology of the area was determined. No abnormal pressures or unusual amounts of contaminating formation such as anhydrite or salt were anticipated.

The mud properties desired while drilling the well were then set forth in a mud program:

Depth, interval	Mud, weight	Fun., visc.	PV	YP	Filtrate	pH
0–2000	9.0	30–40	8	4	10–15	8.0
2000-10,000	9.0	30–34	10	5	6–8	8.0
10,000–12,000	9.0	33–35	14	7	4–6	8.0

A low solids bentonite-CMC-caustic-quebracho mud was used.

After the mud program was outlined, an optimum hydraulics program and operational plan were prepared. The well progressed as planned with no undue trouble.

An appraisal of the relationship between the drilling mud cost and the function of a 4-cone desander while drilling is shown in Table 2.

Table 2. Recap of Drilling Fluid Materials Used in 12,000-ft Mississippi Well.

Product	Quantity-lb	Unit price (cents/lb)	Amount
Bentonite	34,000	0.0235	$ 800
CMC	5,950	0.46	2740
Caustic soda	4,300	0.08	344
Quebracho	4,950	0.17	842
Clay	3,900	0.025	98
Lime	300	0.02	6
		Total	$4830

The following mud materials were used to drill a 12¼-in. hole to 2025 ft and condition same to run 9⅝-in. casing:

Bentonite:	3800 lb @	$0.0235/lb	$ 88.40
Clay:	3900 lb @	0.025/lb	97.75
Lime:	300 lb @	0.02/lb	6.00
	8000 lb		$192.15

This amount, for the purpose of this appraisal, is classified as miscellaneous cost.

An 8⅝-in. hole was drilled from 2025 ft to 12,000 in 24 days. The drilling mud during this period had the following average properties:

Weight, lb per gal	9.3
Viscosity, sec	34
Apparent viscosity, cpe	16
Filtrate, cc	8.8
Cake, 32nd in.	2
pH	8.8
Sand, % by volume	0.5
Plastic viscosity, cpe	13
Yield point, lb per 100 ft²	5

Calipers from wells in this area show that an 8⅝-in. hole will enlarge diametrically to an average of 11¼ in., or have a hole volume 170% of theoretical gage volume. The surface tank volume was 550 bbl.

Make-up water is good. The Ferry Lake formation (10,200 to 10,500 ± ft) is reported to be anhydrite. When this formation was drilled, no drastic change in mud flow properties was noted. However, some anhydrite may have been drilled because increased amounts of CMC and chemical were needed to control the water loss.

The following method was used to estimate the final mud volume.

Hole volume:	$8.625^2 \times 9.975 \times 1.7$	= 1264
Casing volume:	$8.8^2 \times 2.025$	= 157
Tank volume:		550
	Total volume @ 12,000 ft	= 1971 bbl

An estimate of the unit mud cost was based on data contained in literature pertaining to the yield and water loss reducing qualities of a 3% (10.5 lb per bbl) bentonite slurry containing 1.0 lb per bbl CMC, or a ratio of 525 lb of bentonite to 50 lb of CMC.

Pilot tests showed that ½ lb per bbl of caustic soda and ¾ lb per bbl of quebracho would give the proper dispersion and water loss characteristics to match the average properties maintained while drilling to 12,000 ft.

On this basis the following quantities would be required to condition a barrel of native mud:

10.5 lb/bbl bentonite @	$0.0253/lb	0.247
1.0 lb/bbl CMC @	0.46/lb	0.46
0.5 lb/bbl caustic soda @	0.08/lb	0.04
0.75 lb/bbl quebracho @	0.17/lb	0.128
12.75		0.875¢/bbl

The final mud volume cost was then estimated to be:

$$1971 \times 0.875 = \$1725$$

The maintenance cost was estimated to be:

$$\$4830 - (1725 + 192) = \$2913$$

Maintenance cost of $2913 represents the amount spent to maintain the average mud properties for 24 days while drilling from 2025 ft to 12,000 ft. The following method was used to determine the average mud volume:

Mud volume @ 2025 ft (Csg.):

$$(8.8^2 \times 2.025) + 550 = 706$$

Mud volume @ 12,000 ft:

$$(8.625^2 \text{ ft} \times 12 \times 1.7) + 550 = 2070$$

$$2776$$

$$\text{Average Mud Volume (2025 ft to 12,000 ft)} = \frac{2776}{2} = 1388 \text{ bbl.}$$

Maintenance cost is equal to:
Average mud volume (bbl) × dilution factor (%) × unit mud cost per bbl × number of days.

The dilution factor was calculated in the following manner:

$$1388 \times \text{dilution factor (\%)} \times \$0.875 \times 24 = \$2913$$

and

$$\text{Dilution factor} = \frac{2913}{1388 \times 0.875 \times 24} = 0.10$$

or

$0.10 \times 1388 = 139$ bbl of excess mud prepared each day for 24 days.

The average maintenance cost was $121.63 per day while drilling from 2025 ft to 12,000 ft.

Four-cone desander is charged by manifold at right and discharges sand and fine shale directly to pit in background. Engine, lower right directly drives centrifugal pump which charges desander with fluids.

During this period the average weight of the mud was 9.3 lb per gal.

The pounds of total solids entrained in a barrel of 9.3 lb per gal mud equals: $70(9.30 - 8.33) = 67.9$ lb.

Therefore, the amount of native solids plus additives discarded by dilution was equal to:

$$24 \times 139 \times 67.9 = 226{,}000 \text{ lb}$$

At the time the well reached total depth, the mud weighed 9.5 lb per gal. As previously estimated, the total volume of the mud system at that point was 1917 bbl.

The weight of total solids entrained in a barrel of 9.5 lb per gal mud is equal to: $70(9.50 - 8.33) = 81.9$ lb.

The amount of total solids entrained in the total mud system when the well reached total depth was equal to:

$$1917 \times 81.9 = 157{,}000 \text{ lb.}$$

While drilling from 2025 ft to 12,000 ft the following quantity of formation was estimated to be removed from the hole, based on the 8⅝-in. hole having an average diametrical enlargement to 11¼-in. or 170% of theoretical gage volume:

$$11.25^2 \times 85 \times 9975 = 1{,}070{,}000 \text{ lb.}$$

The factor 0.85 is based on solids with an average specific gravity of 2.5.

Spot checks indicated the desander was ejecting an average of 52% of the solids removed

Sand and fine shale removed by desander to improve drilling characteristics of the mud. Water requirements also reduced.

from the hole. This data then makes it possible to estimate the relative function the desander played in removing solids from the mud system. It also makes possible an estimate of the savings on mud cost attributable to the desander.

Weight of drilled solids removed from hole:

(2025 to 12,000 ft) lb =	1,070,000
Weight of additives used (2025-12,000 ft) lb =	45,400
Total weight of solids, lb =	1,115,400
Less weight of solids in final mud system @ 12,000 ft =	− 157,000
	958,400

The 958,400 lb represents the total amount of solids removed by desanding, shaking, settling and dilution.

The following breakdown represents an estimate of the amounts and percentages of solids eliminated by the respective methods.

	Lb	Percentage of Total
Desanding	498,368	52.0
Dilution	226,000	23.6
Shaking and settling	234,032	24.4
	958,400	100.0

Since each barrel of 9.3 lb per gal mud contained 67.9 lb per bbl of total solids — additives plus drilled solids — the desander eliminated the need to jet into the reserve pit the following estimated bbl of mud:

$$\frac{498.368}{67.9} = 7340 \text{ bbl}$$

The cost of maintenance is represented by the amount of mud discarded into the reserve pit. If the unit cost per bbl to condition a bbl of native mud to the average properties was 0.875¢, then this analysis would show use of the desander resulted in an estimated mud cost savings to the operator of:

$$7340 \times 0.875 = \$6420$$

Though water was not considered a cost item, the following calculations show that it had been given a nominal value of 0.25¢/bbl, the following estimated savings would also have been realized.

$$\text{Let: } V_1 = V_2 \frac{(8.33\ S - W_2)}{(8.33\ S - W_1)}$$

Where:

V_1 = Volume of original (water) fluid, lb per gal
W_1 = Initial fluid weight, lb per gal
W_2 = Final mud weight, lb per gal
S = 2.5 (average specific gravity of drilled solids)
V_2 = Final mud volume

Then:

$$V_1 = \frac{7340\ (8.33 \times 2.5 - 9.3)}{(8.33 \times 2.5 - 8.33)}$$

$$= 6768 \text{ bbl water saved.}$$

Cost of water saved = 6768 x 0.25 = $1692

The total savings which then accrue to the operator, if he is also furnishing the water, are:

Mud materials	$6420
Water	1692
	$8112

Mud records from other wells drilled in this area indicate the problem posed for both the operator and the contractor. Mud weights range five to ten points higher than those on the well just analyzed. This higher range of mud weights tends to reduce penetration rates.

Frequently, in an effort to hold mud weights at a minimum by dilution, mud qualities such as a low water loss are sacrificed, and the hazard of bad hole conditions is increased. If an attempt is made to maintain a low mud weight by dilution and still maintain a low water loss, the result is an increase in mud maintenance cost.

The use of a full-flow desander offers one solution to this difficult problem. Weight-building drilled solids can be held to a minimum without an abnormal amount of dilution. This helps the contractor increase his rate of penetration. A low water loss drilling fluid can be carried at a reasonable cost. This gives the contractor the added protection he needs to carry on a fast, safe drilling operation without increasing drilling mud maintenance cost to the operator.

About the Author

R. J. Duran is drilling fluids supervisor for Loffland Brothers Company, Tulsa, Oklahoma. In 1943 he joined Baroid Division of National Lead Company and for two years worked as a well logging engineer in West Texas before transferring to the drilling mud department. He was a drilling mud service engineer in the Ark-La-Tex area and later was a superintendent in that area until 1955 when he was transferred to Casper, Wyoming, in charge of a district covering Wyoming, northern Colorado, Nebraska and northern Utah. He joined Loffland Brothers in 1959.

Acknowledgment

For permission to publish this paper, the author expresses his appreciation to the Loffland Brothers Company, and thanks Loffland Brothers personnel who made possible the accumulation of data and success of this study.

Reference

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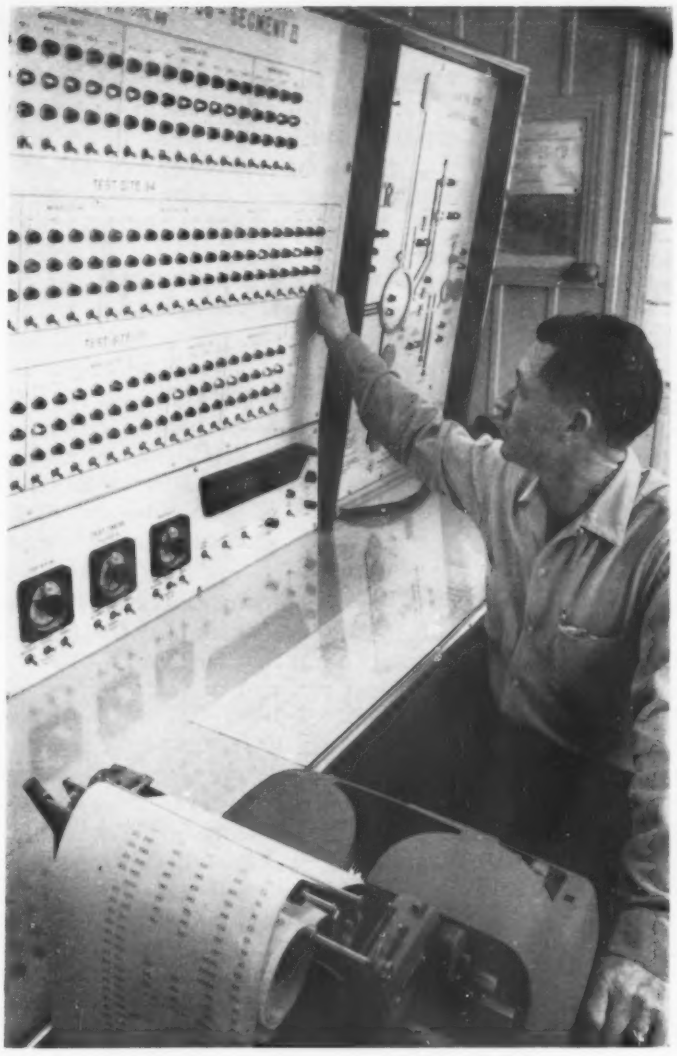


Mobil Engineering Supervisor N. E. Bourland at console of the electronic "brain" that supervises and monitors automatic production operations on 50 wells.

Ultimate in Automation: Push-Button Pumping

Just dial a number on a central electronic control panel and 50 wells in a 3400-acre area can be shut down, returned to production and tested, either individually or automatically in sequence.

All test and production data complete with well number, time and date are automatically printed at the control center for a full and permanent record.

This is just a sample of what one of the world's most efficient and fully automatic systems for producing and gathering oil can do.

The electronic supervisory control and monitoring system was installed by Mobil Oil Co. in Segment 2 of the giant SACROC unitized pressure maintenance project in Scurry County of West Texas, about six miles northwest of Snyder.

Current production from the automated portion amounts to over 97,000 bbl per month.

The unique system already has enabled Mobil to substantially reduce its maintenance and operational costs by trimming number of tank batteries from 13 to 1, provide faster and more complete control of producing wells and recover and sell additional gas.

The central console, connected by telephone lines to eleven remote field stations, enables the operator to constantly monitor automatic transfer of oil to the pipe line, operation of all central tank battery equipment, changes in the status of any well and oil production volumes.

Certain alarm conditions such as high fluid levels in tanks or extremely low flowing pressure will cause the system to use a built-in ability to "think" and then automatically take the proper corrective action.

Mobil is considering construction of five more similar projects in Segment 2 of SACROC unit. ■

by Wallace B. Johnson

Texas' Deepest Producer Has Heaviest Tubing

Texas' deepest producer to date, Atlantic Refining Company's recently completed J. C. Kelley No. 1 in the Delaware Basin of Pecos County, uses a record-setting tubing string — 3767 ft of 4½-in. OD by 3.64-in. ID and 12,001 ft of 4-in. OD by 3.34-in. ID.

The well, located approximately 30 miles west of Fort Stockton in the Hershey (Devonian-Fusselman-Montoya) field, is the discovery well for the field and is perforated from 15,831 to 16,680 ft in the Devonian, Fusselman and Montoya gas zones. These zones have been classified as a common reservoir and are produced as a single zone through one string of tubing.

Deep production and corrosive gas necessitated the combination string of heavy tubing.

Why Such Large Tubing?

Information available when the completion was designed indicated that producing rates of 40 to 50 MMcf per day with pressures in excess of 5000 psi at the wellhead could be expected from the well. Experience in other areas had shown that corrosion and/or erosion of tubing is greatly accelerated if producing rates exceed 10 MMcf per day in 2-in. tubing or 18 MMcf per day in 2½-in. tubing. Based on this generality and assuming pressures to be equal, the problem was approached on the basis of flow rate.

By comparing internal cross-sectional areas of various sizes of tubing, the estimated maximum safe rates were found to be:

Tubing Size	Flow Rate
3½-in. OD, 9.3 lb/ft	27 MMcf per day
4-in. OD, 11.0 lb/ft	36 MMcf per day
4½-in. OD, 12.7 lb/ft	47 MMcf per day
5-in. OD, 18.0 lb/ft	58 MMcf per day

This indicated that the 4½-in. tubing was within the desired range. The design was approached in the same manner as casing: safety factors of 1.125 for collapse, 2.0 for tension (with buoyancy) and 1.10 for burst.

With 10-lb-per-gal mud in the annulus, collapse pressure of 16,000 ft is 8300 psi. Therefore, with a safety factor of 1.125 and no pressure inside the tubing, the required collapse resistance should be 9340 psi. However, since the possibility of having no pressure inside the tubing at 16,000 is so remote, the safety factor could be reduced.

A design safety factor in collapse of 1.0 was selected as the lower limit. The largest size of API standard-weight tubing that would meet the requirement of 8300 + psi collapse is 3½-in. OD, 9.3 lb per ft, N-80 (8580 psi) or P-105 (11,610 psi).

At this point, it became apparent that if a larger tube was to be used it would have to be heavy-wall. Grade D drill pipe, 4½-in. ID, 20 lb per ft, would have a collapse safety factor of 1.015; Grade E would have a safety factor of 1.25.

Another requirement was to keep the metal as soft and ductile as possible. To reduce the possibility of stress corrosion cracking, the stress level was specified to be below 60% of minimum yield and maximum hardness was set at Rc22.

Hardness requirements dictated the use of Grade D material rather than Grade E. Grade D drill pipe material is comparable to J-55 tubing and was acceptable for collapse but would not meet requirements for tension. However, the minimum yield specifications were increased from 55,000 psi to 65,000 psi to improve tensile strength.

Consideration was also given to the methods of running a string of 4½-in. Grade D tubing to 16,000 ft. Three methods were studied: (1)

running tubing in two sections, (2) floating tubing in with special plug, and (3) running a tapered or combination string of 4½-in. and 4-in. tubing. The first two considerations were ruled out as being too complicated and adding to the undesired in-hole equipment. The third, a combination string, was selected as being the most practical from all standpoints when compared with the first two.

Final calculations led to the decision to run 3767 ft of 4½-in. OD tubing and 12,001 ft of 4-in. OD tubing. This combination gives a tension design factor of 1.7 for both sections, based upon the minimum yield strength and the buoyant weight of the tubing.

Collapse design factor is 1.03 at 16,000 ft with 10-lb-per-gal mud in the annulus and empty tubing. As stated previously, this low collapse factor was of no practical concern, since it would be difficult to void the tubing completely of pressure at 16,000 ft. Also, no in-hole wireline tubing plugs or chokes were to be used in the tubing string.

With a maximum surface pressure of 7000 psi, the design factor in burst is 1.55 at the top joint.

Tubing Specifications

After the basic tubing design was completed, the strings were manufactured to special order in accordance with applicable portions of API 5-A specifications and certain additional specifications. Defect limits specified were: (1) Outside of tube body, including upset slope surface, 12½% if grindable; (2) no defects on outside finished flat or threaded joint; (3) inside of the tube body 12½% and (4) no defects on inside of finished bore of joints. All tubing was normalized full length and tempered after upsetting.

Hardness tests were performed at the mill with four tests per joint. The tubing was in-

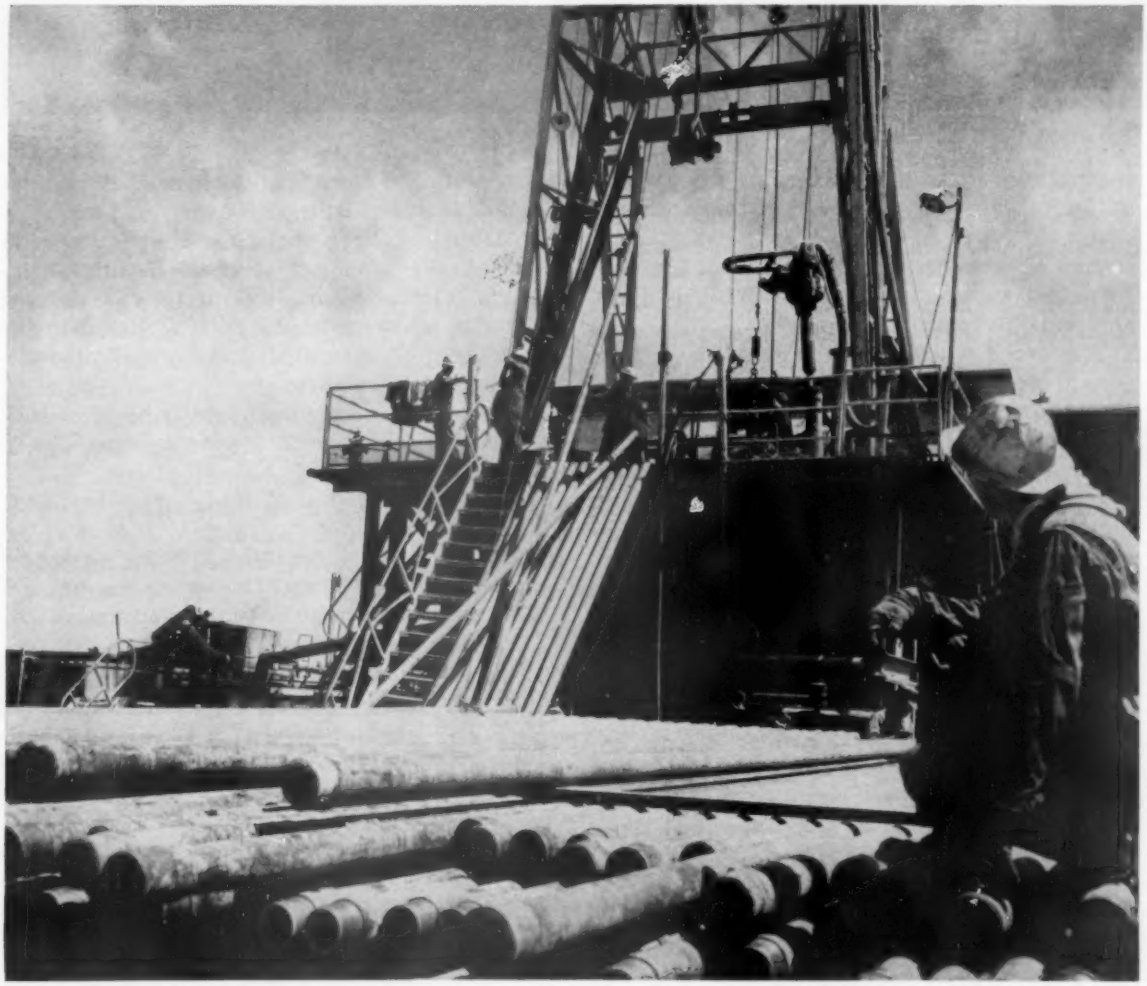
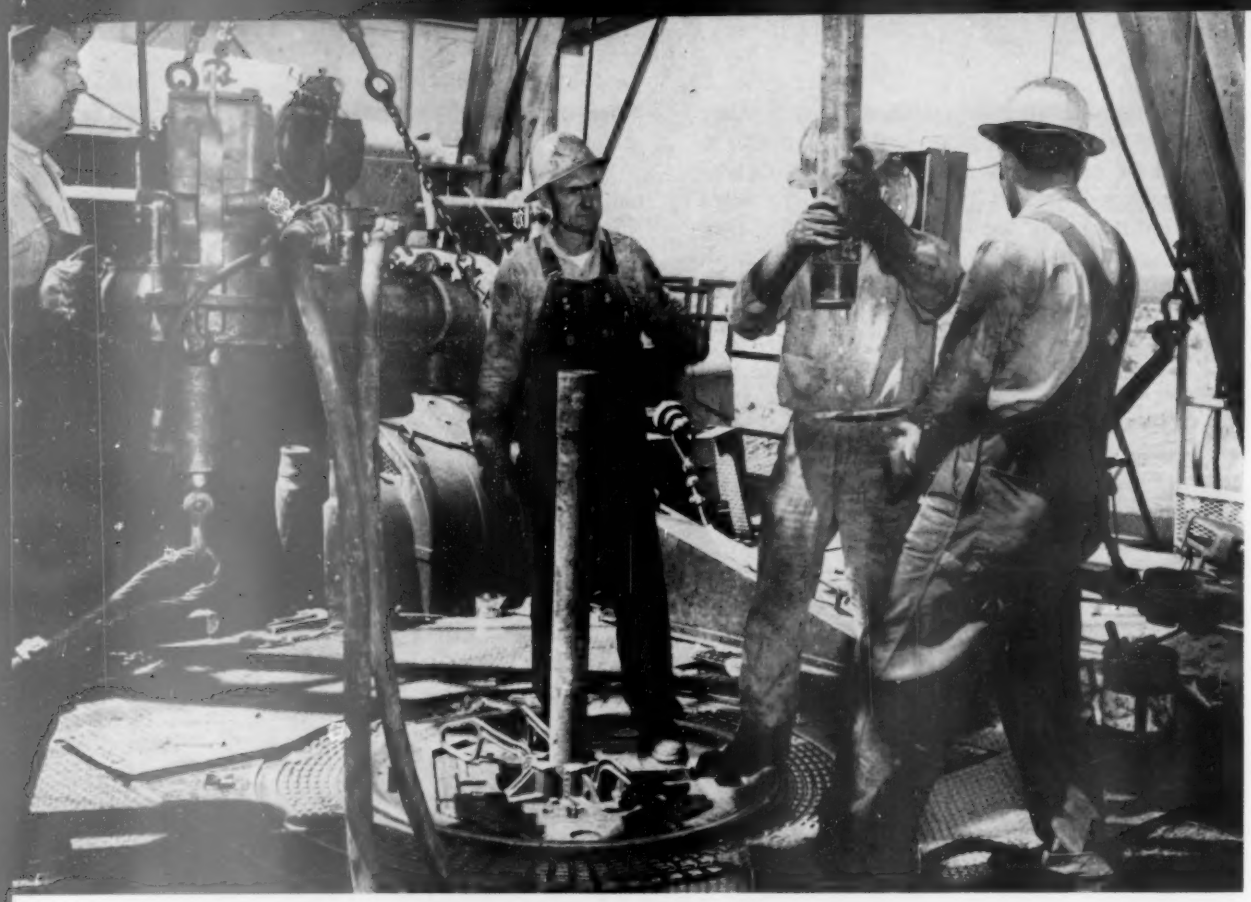


Fig. 1. Heavy-wall 4½-in. tubing, looking like drill pipe, is run into Texas' deepest producer — Atlantic Refining Company's J. C. Kelley No. 1 in the Delaware Basin of Pecos County.



spected with electronic instruments, after which all joints were given a special end-area inspection.

Cost of tubes with a defect limit of 5% was compared with cost of those with 12½% limit and found to be about 15% higher.

The decision was made to have the tubing plastic coated without specifying a coatability inspection. Economics indicated it would be cheaper to coat the tubing, run a holiday detector, and re-coat those joints with holidays. Less than 5% of the tubing failed to pass the holiday detector on the first inspection. These joints were reprocessed and the final result was that less than ½% of the tubing would not coat holiday-free. These joints were mechanically sound but contained some surface imperfections that could not be plastic coated holiday-free.

Table 1. Specifications of 4½-in. and 4-in. Tubing (AISI 1340 Carbon Steel)

	4½-in. OD	4-in. OD
Plain end weight, lb/ft	18.69	12.93
Inside diameter, in.	3.64	3.34
Outside diameter, in.	4.50	4.00
Wall thickness, in.	0.43	0.33
Joint OD, in.	5.14	4.50
Tension Strength (Minimum Yield), lb	338,000	247.000
Internal yield, psi	10,830	9400
Collapse strength, psi	8550	8500
Yield strength, psi	65,000-70,000	65,000-80,000
Maximum hardness	Rc 22	Rc 22
Normalized	Full Length	Full Length
Joint efficiency, %	108	111

After inspection of the upset tubes was completed, the tubing was threaded with an integral joint with a modified buttress thread and a teflon seal ring at the bottom thread in the box. After threading, all joints were hydrostatically tested to 8000 psi.

Table 1 shows the final specifications of both lengths of tubing.

Running Tubing

Running the large tubing string presented some special problems. The string was handled as casing rather than as tubing and was run by a regular casing crew.

All threaded joints were thoroughly cleaned and lubricated with a thread dope containing 60% powdered zinc and 40% lime soap grease. Torque make-up was controlled with hydraulic tongs with a torque recorder to the manufacturer's recommendation of 1800 ft-lb for the 4-in. and 2000 ft-lb for the 4½-in. tubing. A tubing stabbing guide was used to prevent chipping the plastic coating on the pin nose.

Before the tubing was set in the packer, completion fluid was circulated into place. A treated brine was left in the annulus. The packer was set at 15,800 ft.

Fig. 2. Casing crew ran the special combination tubing string using side-door casing elevators and power tongs with torque recorder. Note plastic coating on end of pin.

Fig. 3. Box end of heavy-wall tubing shows modified buttress thread and teflon seal ring at the bottom thread in the box.

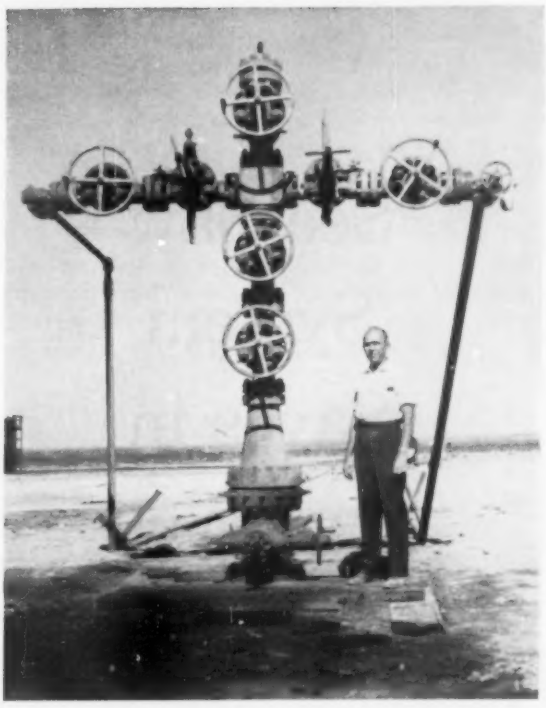


Fig. 4. Special wellhead, featuring solid stainless steel for all equipment exposed to gas flow, towers over author. All equipment in the Christmas tree is rated at 10,000-psi working pressure.

It was necessary to construct a support for the 13⅜-in. surface casing to help carry the load of the large tubing. The surface casing was loaded with full weight of the 9⅝-in. intermediate string and about 300,000 lb of the 7-in. casing. These loads plus the weight of the tubing (202.000 lb in 9.7 lb per gal brine) was well in excess of the load capacity of the 13⅜-in. surface string.

The cellar was excavated to solid caliche and a reinforced concrete base was poured 18 in. thick by 8 ft in diameter. A steel base 1½ in. thick and 32 in. in diameter was then set on top of the concrete and welded to the 13⅜-in. casing head.

Wellhead Equipment

After selection of the combination of 4½-in. and 4-in. tubing string, the problem of a suitable wellhead was encountered. With the expected high velocities of gas flow, it was deemed necessary that the master valves be equal to or of greater internal diameter than the tubing string. Valves selected were 4 1/16-in. ID and of solid stainless steel.

The next consideration was flow after the master valve. Alternatives were to use a right-angle turn or to construct a large "U" of special pipe. It was found to be more practical to use a block cross and to direct flow out both sides.

Carbon dioxide and hydrogen sulfide content of the gas called for use of solid stainless steel for all wellhead equipment exposed to the gas flow (tubing head adapter, master valves, block cross, swab valves, safety and wing valves).

The Christmas tree assembly is 10-in., API 5000 psi by 9-in., API 10,000 psi. All equipment is rated at 10,000-psi working pressure. Safety valves and wing valves are 3 1/16-in., API 10,000-psi flanged valves.

Special consideration was given to plugging the tubing during completion operations. This was accomplished by using a special tubing head adapter which has a sat for a plug. The pack-off takes place in a special stainless steel mandrel which prevents damage to the plastic-coated tubing.

After completion, a production test of the well showed gas flow of 32.6 MMcf per day through a 1-in. choke with surface tubing pressure at 1700 psi. After shut-in, tubing pressure at the surface registered 5500 psi.

Wallace B. Johnson, District Production Engineer, Atlantic Refining Company, Odessa, Texas.

■

"See-Saw" System Saves in Two-Well Pumping

by Blaine Johnston

A unique hydraulic "see-saw" system for pumping two parallel, twin or offset wells has offered substantial savings in several Texas and Oklahoma installations. Its selection over alternate equipment considered in one case has saved an estimated 30% in initial investment and, in another case, slightly less than 50%.

The system is rod-counterbalanced hydraulic pumping. The idea connects two long-stroke/slow-speed hydraulic units so that the rods in one well go down while the rods in the other well come up to maintain counterbalance by hydraulics.

Principle of Operation

Principle parts of the system shown in Fig. 1 consist of control cylinder, slave cylinder, power pump, booster pump, reversing valve, and reservoir.

One cylinder is installed on the wellhead of each well or zone to be pumped. The piston in each cylinder is attached to a polish rod which extends through a packing gland then connects to the sucker rod string.

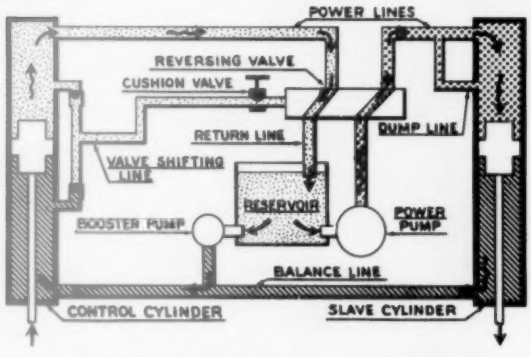


Fig. 1. Control piston on upstroke.

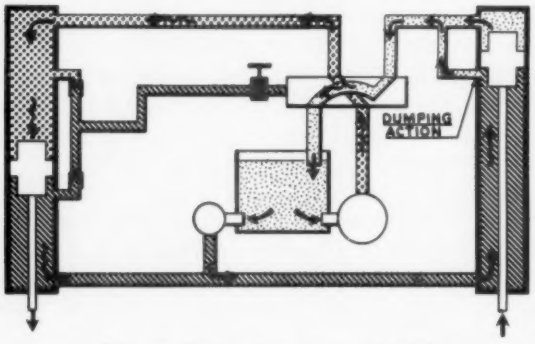


Fig. 2. Slave piston on upstroke.

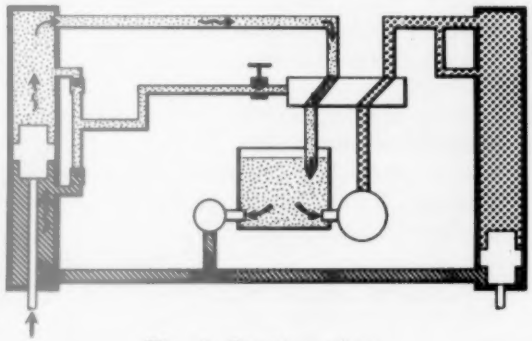


Fig. 3. Starting phase.

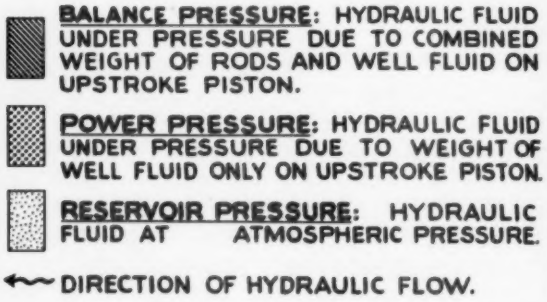

BALANCE PRESSURE: HYDRAULIC FLUID UNDER PRESSURE DUE TO COMBINED WEIGHT OF RODS AND WELL FLUID ON UPSTROKE PISTON.
POWER PRESSURE: HYDRAULIC FLUID UNDER PRESSURE DUE TO WEIGHT OF WELL FLUID ONLY ON UPSTROKE PISTON.
RESERVOIR PRESSURE: HYDRAULIC FLUID AT ATMOSPHERIC PRESSURE.
DIRECTION OF HYDRAULIC FLOW.

Fig. 4. Legend for fig. 1, 2, and 3.

A balance line (Fig. 1) connects the lower end of the slave cylinder to the lower end of the control cylinder. Connected at the upper end of each cylinder are power lines which conduct hydraulic fluid to and from the reversing valve.

At the upper and lower ends of the control cylinder are valve ports which open into a common conduit with line check valves at the upper and lower ends of this conduit. Between the check valves, the valve shifting line branches out on this common conduit and runs ahead of the reversing valve.

The slave cylinder has no controls except for a port near its upper end which opens to the dump line. This line connects back into the power line of the slave cylinder.

Other components shown in Fig. 1 are mounted on the power unit skid. The power pump is a high-volume, low-pressure rotary pump, the suction of which is connected to the reservoir and its discharge connected to a port in the reversing valve. A pressure relief valve (not shown in Fig. 1) connects the discharge line back into the reservoir in case of overload. The booster (or make-up) pump also takes suction from the reservoir but it discharges directly into the balance line of Fig. 1. The booster pump is also a rotary pump of high-pressure, low-volume design. There is also a pressure relief valve (not shown in Fig. 1) on the discharge of the booster pump. Both pumps are driven by the same prime mover mounted on the power unit skid. The return line carries fluid from a port in the reversing valve to the hydraulic fluid reservoir. The reversing valve shown schematically is a spool-type pilot valve and special four-way spool-type main valve.

FIG. 5. Quadrapod mounting of cylinders above a dual producer near Freer, Texas. Production is from around 2200 ft.

Control Piston on Upstroke

Sequence of operations during the upstroke of the control piston is shown in Fig. 1. The power pump discharges through the reversing valve and power line into the top end of the slave cylinder. This forces the slave piston downward against the balance fluid which communicates with the bottom end of the control cylinder through the balance line in a U-tube effect. The control piston is driven upward. As fluid in the upper end of control cylinder discharges through its power line and reversing valve, into the reservoir at atmospheric pressure, the control piston is free to move upward. The booster pump discharges continuously into the balance line and makes up any balance fluid lost from beneath the two pistons.

As the control piston passes the upper valve port, balance fluid is introduced through the valve shifting line into the head of the reversing valve, and shifts it. The speed of shifting is governed by the setting of the needle cushion valve that restricts flow into the reversing valve. This restriction allows a gradual deceleration of the control piston and of the slave piston, for the latter is governed entirely by the action of control piston. When the reversing valve reaches the mid-point of its shift, both control and slave pistons have come to a stop and are ready to reverse their directions.

Slave Piston on Upstroke

Fig. 2 illustrates operating sequence of the slave piston on the upstroke. When the reversing valve completes its shift, the reversing valve "crosses over" and the power pump fluid is now being directed to the top of the control piston. The upper end of the slave cylinder is vented back to the reservoir and causes the control piston to move downward. The slave piston is forced upward

Fig. 2 also illustrates the "dumping" action of the slave piston. As the booster pump makes

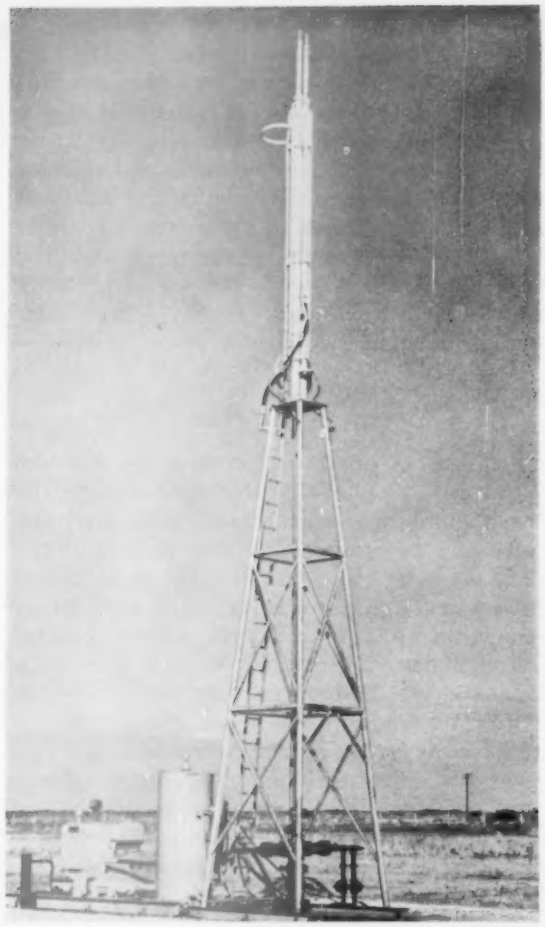


FIG. 6. Quadrapod mounting on 7500-ft dual well that permits a slightly wider center-to-center spacing of both cylinders.

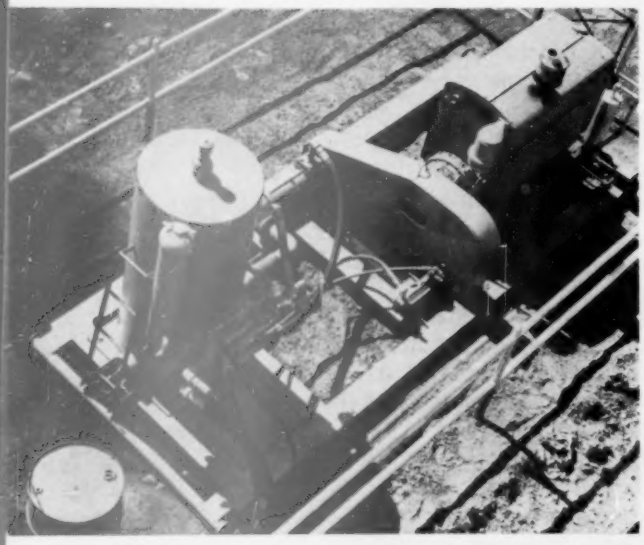


FIG. 7. Power unit on a 9500-ft off-set well showing power pump (behind reservoir tank) and booster pump. Both are driven by same engine.

up losses from the balance system, it is necessary only to operate this pump at an output volume slightly in excess of anticipated losses. This operation means that, as the system continued to operate, separation of the two pistons would become greater and greater until the slave piston would eventually bump the top of its cylinder unless some method of getting rid of the excess fluid were employed. This method is accomplished by the "dump" port which allows the slave piston to "wait" while the control piston completes its downstroke. In this manner, both pistons are always in phase and of a consistent stroke range and length.

As the control piston passes the lower valve port, the reversing valve is now free to exhaust through the valve shifting line into the control cylinder above the piston.

Starting Procedure

Before power is applied to the system, both pistons are resting at the bottom of their respective cylinders as shown in Fig. 3. Before normal operation can commence, it is necessary to get one of them up while the other is down. As the pumps start, the following sequence of events automatically take place: (1) the booster pump immediately builds up pressure and positions the reversing valve as shown in Fig. 3. This allows power pump to discharge on top of the slave piston; (2) the power pump bypasses through its relief valve and firmly holds the slave piston against the bottom; (3) the booster pump slowly pumps the control piston upward, since this piston has atmospheric (or reservoir) pressure on its top end; (4) the control piston passes the upper valve port and shifts the reversing valve; and (5) normal operation as in Fig. 2 begins.

When it is necessary to bleed off pressure from the system, both pumps are stopped and the booster pump relief valve is opened manually. This allows both pistons to settle to bottom, when all pressure is gone from the system.

Analysis of Operation

It is apparent from Fig. 1 through 3 that if friction is neglected and the well fluid level is assumed at pump intake on the upstroke well, the upstroke piston lifts the weight of well fluid on the net plunger area. The rod string weights will cancel out except for the buoyancy effect in the downstroke well. Balancing can be assured by using identical rod strings if wells are the same depth or by weighting the rod string on the shallower well if there is any great variation in depth. This buoyancy

adds to the load on the upstroke well so that the upstroke piston can be considered as lifting the well fluid weight on the *gross* plunger area. Power required is that which can lift the gross fluid weight on the given plunger size. This power is in contrast to that of a single-counterbalanced pumping unit of any type. Power required by the single units is only that amount necessary to move one-half of the gross plunger load. It must be remembered that the rod counterbalance system is pumping two wells.

The balance pressure is that required to lift the rod weight plus net fluid weight in the upstroke well, plus an acceleration load. This circuit is not a dynamic one for the hydraulic fluid simply serves as a means of transmitting power and movement from one piston to the other. If there were no fluid losses, the booster pump would be unnecessary except for the original charging operation as shown in Fig. 3.

Surface Equipment

The cylinders can be mounted on the well in a variety of ways, but for parallel, dual units, the quadrupod, as shown in Fig. 5 and 6, is the most popular. This mounting permits a slightly wider center-to-center distance for the two cylinders than is possible down at the wellhead. It has been found by experience that this slight drift of the polish rods does not cause packing trouble and that it is unnecessary to stagger the cylinders or offset the rod couplings. Where a single cylinder is mounted on a well (Fig. 8) the short support cage can be mounted on the pumping tee, or, with an adapter it may be mounted on the casting flange. This support cage mounting can be used on dual wells, where the centers of the two tubing strings are identical with the cylinder centers.

Power units vary in capacity from 7-hp to 270-hp and are skid-mounted with provision for any type or make of prime mover (Fig. 5, 6 and 7). The power and booster pumps are driven by the same prime mover. The reversing valve and relief valves are mounted on a control panel attached to the side of the reservoir. All piping converges to this panel.

Offset Well Installations

The operating principle and most of the equipment are the same on offset installations as on dual completions. The main difference is that the balance line and one power line must

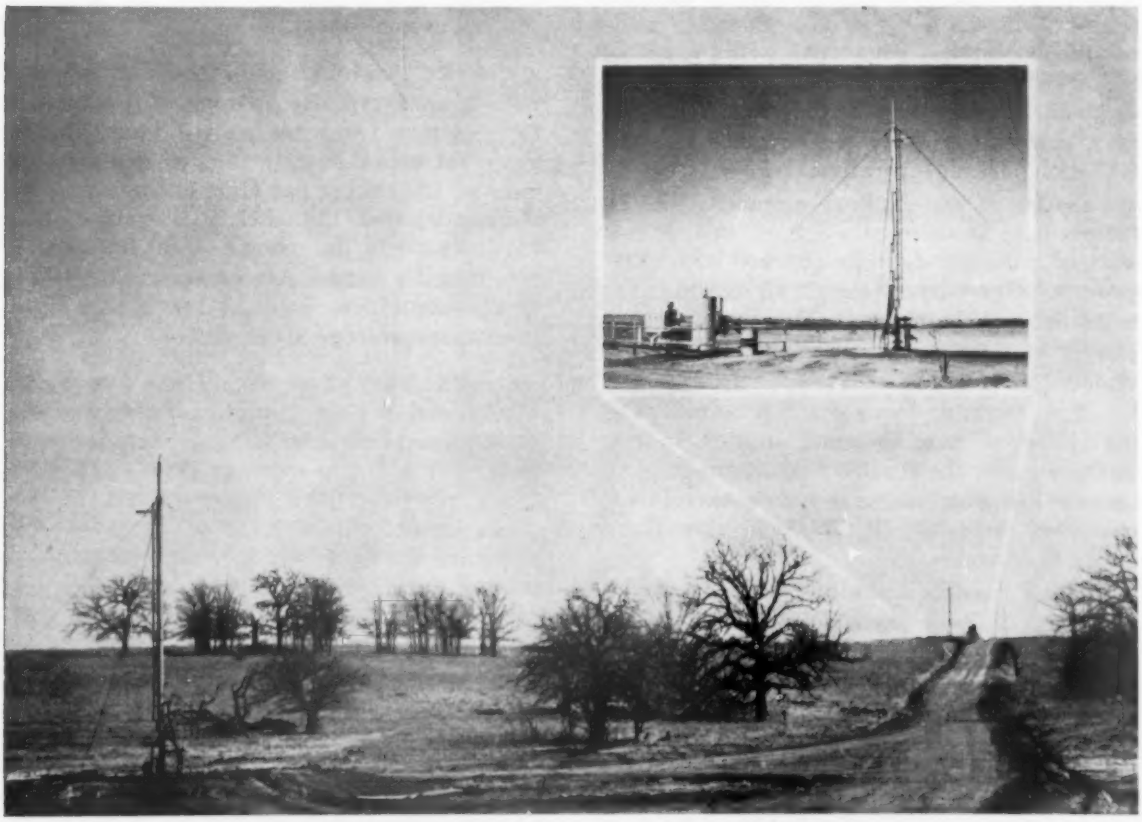


FIG. 8. Two off-set wells on 40-acre spacing produce from around 9500 ft. Both wells are equipped for dual pumping using a single control and power unit located at well in inset.

be approximately the same length as the distance between the two wells. The power unit is placed near the well with the control cylinder to minimize length of the valve shifting line.

A pipe diameter is selected for the two long lines that will minimize pressure drop. In practice, a pressure drop of 50 to 100 psi is usually not prohibitive. In smaller sizes, standard line pipe can be used. In larger sizes, seamless pipe is recommended.

Use of electric resistance-welded pipe is recommended over regular line pipe because it is stronger and cheaper in the X-42 and X-46 grades where a thin wall may be used safely. The type of pipe with one end belled is best. It permits the small end of the next joint to be inserted into the bell and fillet welded. This keeps slag and debris out of the line.

Limitations of System

To gain the economic advantages inherent in this method of oil well pumping, there must be two wells or two zones. Because the two units are connected together in a single hydraulic system, it is necessary to employ an auxiliary counter-balance attachment if one well or zone operates alone. This would be the case in new wells where one well was completed and the second well was being drilled. Pumping could be started on the completed well by use of the counterbalance attachment. This same attachment can also be employed when it is necessary to work over one well (or zone) in an installation already operating.

Function of the auxiliary counterbalance attachment is to serve as a second well. It consists of a dummy cylinder charged with nitrogen and other connections . . . all of which can be trailer or skid-mounted. The unit functions exactly as a second zone or well. The nitrogen replaces the role of the rods.

Large hydraulic volumes and wide well spacing (160-acre) pose another limitation. In some of these cases, the auxiliary counterbalance attachment might be employed as permanent equipment especially if the long, slow pump stroke is desirable.

Another possible limitation results from wide variations in well depths. In many of these cases, weight of rod strings of different lengths can be balanced by using different sizes.

Two zones or wells produced at widely different fluid rates can be handled in many cases by using different size bottomhole pumps. For example, one operator wanted to pump 400 bbl per day from one well and 100 bbl per day from the offset well. Since both wells were equipped with 2½-in. tubing, the problem was solved by installing a 2¼-in. pump in one well and a 1$\frac{1}{16}$-in. pump in the other well. Eventually, both wells would be pumping at the same higher rate. But, in the initial setup, power demand would vary considerably. Total power consumption is that required to move the given volume of fluid from each well. There would be no undue stress on the prime mover due to these fluctuations since the system operated at six or seven strokes per minute.

Another solution to the variable fluid problem is to by-pass periodically by time-clock or manually fluid production from the smaller well back into its casing annulus. Fluid pounding is prevented and power consumption is reduced.

Field Installations

Case 1: This installation, shown in Fig. 5 and located near Freer, Texas, is a dual, quadrupod-mounted unit with electric motor drive. Both cylinders have a 2½-in. bore and 36-in. stroke, operating at eight strokes per minute. Displacement rate is about 46 bbl per day from each zone. Depth of each pump is near 2200 ft. Although this particular unit works at only about half capacity, estimated saving in initial investment is about 30% under the alternate equipment considered.

Case 2: This dual quadrupod unit powered with a multi-cylinder gas engine, pictured in Fig. 6, pumps two zones in a well near Palacios, Texas, at approximately 7500 ft at a displacement of 130 bbl per day from one zone and 100 bbl per day from the other. It is equipped with 1½-in. and 1$\frac{1}{16}$-in. pumps. Cylinder bore is 4½-in. with a 12-ft stroke, operating at six strokes per minute. Estimated savings in initial investment average about 40%.

Case 3: This offset installation, pictured in Fig. 7 and 8 near Healdton, Oklahoma, has some unusual aspects. Distance between wells is 1320 ft (40-acre spacing). There is a dual-zone pump in each well, making a total of four zones pumped with two rod strings. Producing zones are at 9000 ft and 9500 ft. Both cylinders have a 5-in. bore to produce a displacement rate of about 115 bbl per day in each well. Connecting fluid lines are electric resistance welded pipe, X-42 Grade, 3½-in. OD by .125-in. wall. The total installed price of unit, pipe, engine, and all surface equipment except wellhead, was slightly less than 50% of alternate proposals.

Blaine Johnston is vice president of Engineered Oil Tools, Inc., Houston, Texas.

■

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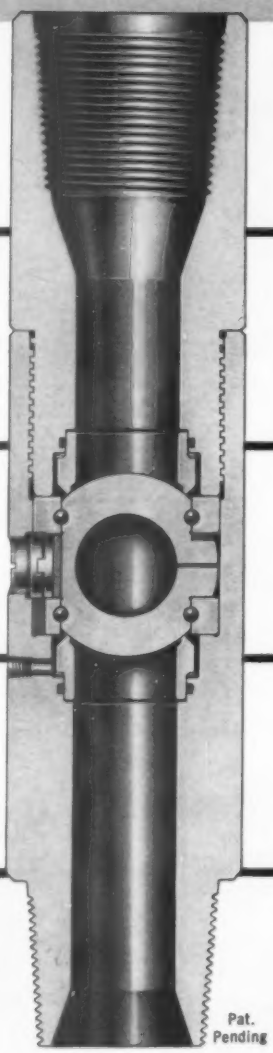

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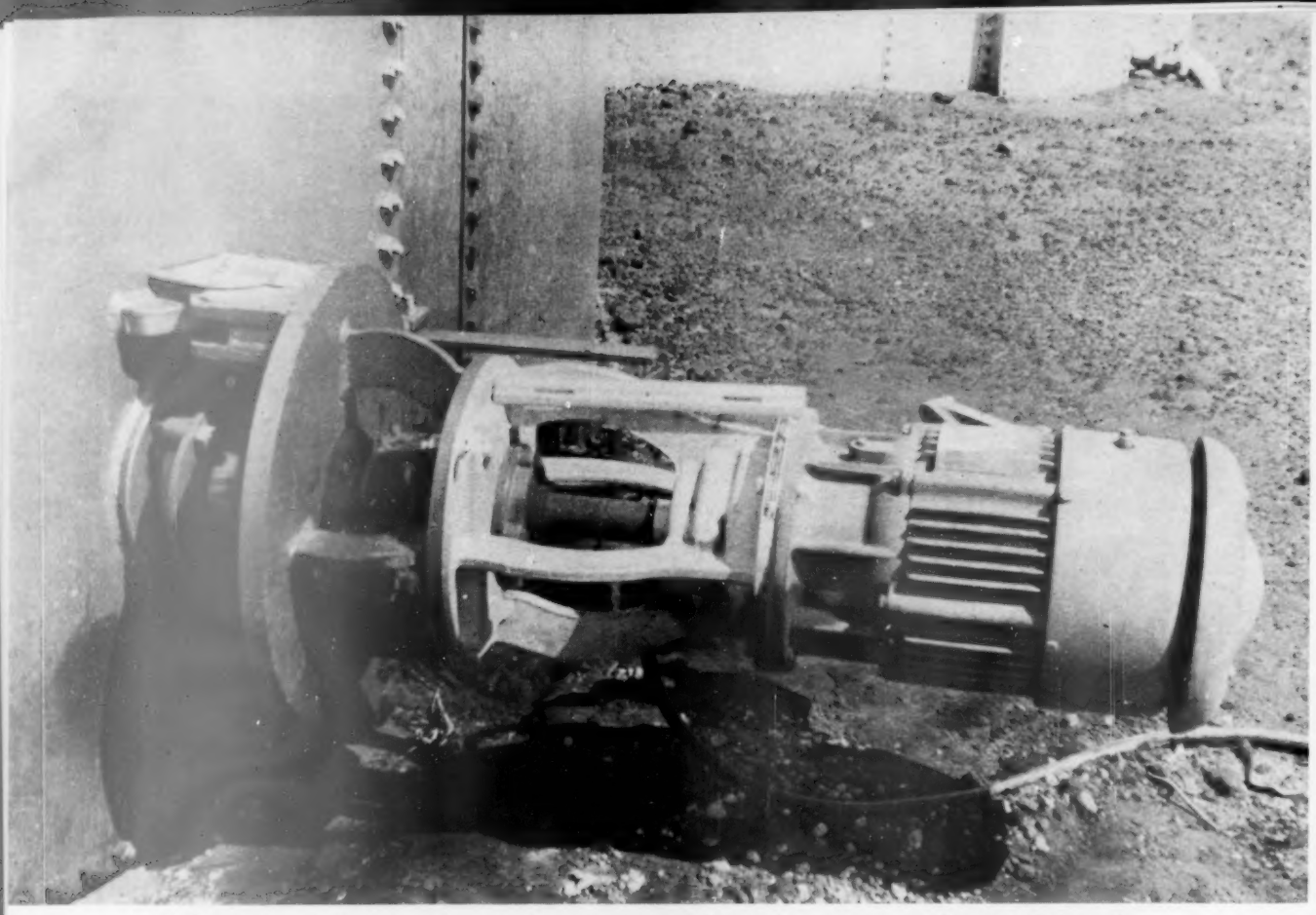


FIG. 1. Electrically-driven lease tank mixer on variable-angle mounting can be rotated through a 40-deg arc for thorough tank bottom mixing. One-ft ruler on mounting indicates size.

Mixing Pays Off in Lease Tanks

by George A. Savary

An electric-powered mixer has proved its worth in a 1000-bbl lease tank for A-P Division of Union Texas Natural Gas Corp.

This type of mixer was originally much larger and was developed for use in 20,000-bbl and larger storage tanks.

Its use in a one-year trial in the West Seagraves field of West Texas:

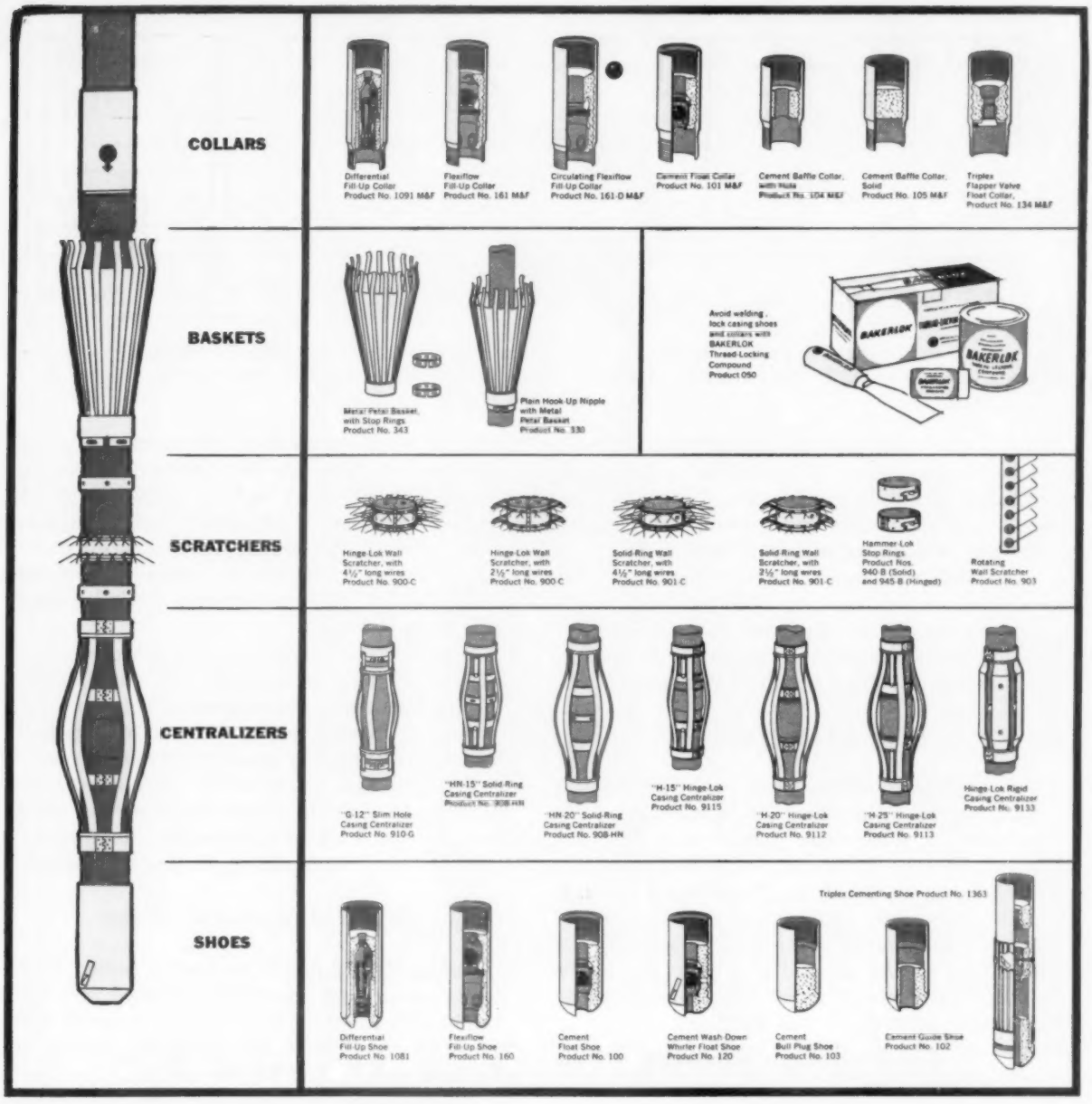
1. Completely eliminated undesirable tank bottom accumulations.
2. Proved the stock tank oil would stay within the 1% BS&W content specification of crude sold to the pipeline company.
3. Broke up heavy ends and basic sediments which tend to block drainage of water and other impurities.
4. Eliminated need to periodically clean out bottoms.
5. Made it possible to by-pass heater-treaters. Gun-barrel separation proved satisfactory in conjunction with tank mixing.

The test installation is shown in Fig. 1.

Previous Treating Practice

During the early life of the West Seagraves field (located 8½ miles east of Denver City), emulsion treaters were used to reheat stock tank oil to return a portion of the tank bottoms to solution. After gas production fell off, butane was used to fire the emulsion treaters.

Heater-treaters were removed once it was determined that gun-barrel separation, coupled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Cement Baffle Collar, Solid Product No. 105 M&F
Triplex Flapper Valve Float Collar, Product No. 134 M&F
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Metal Petal Basket, with Stop Rings Product No. 343
Plain Hook-Up Nipple with Metal Petal Basket Product No. 330
Avoid welding, lock casing shoes and collars with BAKERLOK Thread-Locking Compound Product 050
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Hinge-Lok Wall Scratcher, with 2½" long wires Product No. 900-C
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Rotating Wall Scratcher Product No. 903
CENTRALIZERS
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"HN-20" Solid-Ring Casing Centralizer Product No. 908-HN
"H-15" Hinge-Lok Casing Centralizer Product No. 9115
"H-20" Hinge-Lok Casing Centralizer Product No. 9112
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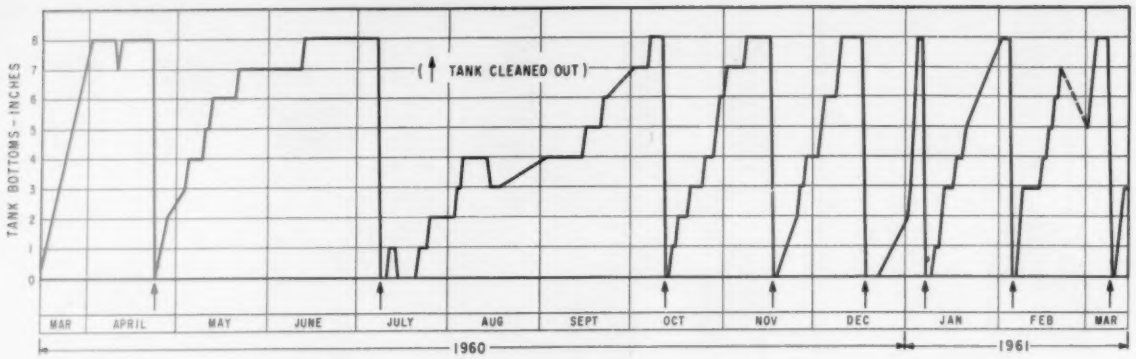

FIG. 2. Tank bottom build-up rate over a 12-month period in tank No. 84958 on the H. L. Webb No. 2 battery. This tank was not equipped for tank mixing.

with a chemical emulsion breaker and the heat retention properties of the produced fluid, was sufficient to obtain pipeline oil. As a result, the high cost of butane was eliminated but the problem of tank bottoms still existed.

Chemical compounds containing some partial colloidal suspension properties proved ineffective. Some of the unsuccessful attempts included batch treating the bottoms or use of dry ice to effect a rolling action in stored crude oil.

Pilot Mixer Installed

To explore possible advantages of mechanical agitation in minimizing or eliminating tank bottoms, a pilot tank mixer was installed March 15, 1960, in one of two 1000-bbl capacity stock tanks at the H. L. Webb No. 2 battery. Both tanks were cleaned out and each alternately filled and run into a pipeline with Siluro-Devonian oil. At the end of a year, the mixer results were graded most favorable since the following conditions were fulfilled:

1. Tank bottoms were eliminated in the mixer tank.
2. Re-suspending tank bottoms did not contaminate the oil beyond the 1% BS&W pipeline turndown point.
3. There were no detrimental effects to the inside of the tank due to the blasting effect of the mixer.
4. A reasonably attractive payout period was indicated.

No bottoms were obtained in the stock tank with mixer, while its companion tank required eight cleanouts during the one-year test period at an estimated cost of $320. When bottoms build up 8 in. or more, the pipeline company servicing the area will not take further oil until the bottoms are lowered or removed.

Seasonal build-up rates of the companion tank are shown in Fig. 2. These data show ambient temperature fluctuations exert a great influence on the rate of bottom deposition. About 90% of these tank bottoms consist of paraffin, most of which would remain in suspension or solution in the stock tank oil if retained in an environment above the "cloud point," which for this Devonian oil is between 80 and 85 F.

Tank bottom heights in Fig. 2 were determined by thiefing through the gage hatch. Build-up reversals between several cleanout periods are apparent. This is believed to be caused by daily thiefing in a localized area, minor stirring attributed to incoming production; an increase in ambient temperature of the stock tank oil which would increase its solubility for paraffin or, a combination of all these factors.

Base Sediment and Water

During this 12 month evaluation period, both stock tanks were alternately emptied into the pipeline 23 times each. A numerical count was made of the BS&W shake-outs as shown in Table 1.

Table 1 shows Tank No. 84957 equipped with a mixer was emptied two times when the

Table 1. Base Sediment and Water Content by Shake-Out Tests vs the Number of Times Each Tank Was Emptied.

BS&W %	Number Times Tanks Emptied	
	Tank No. 84957 (with mixer)	Tank No. 84958 (without mixer)
1.0	0	0
0.9	2	0
0.8	8	0
0.7	2	0
0.6	6	0
0.5	3	0
0.4	1	0
0.3	0	3
0.2	1	20
0.1	0	0
	23	23

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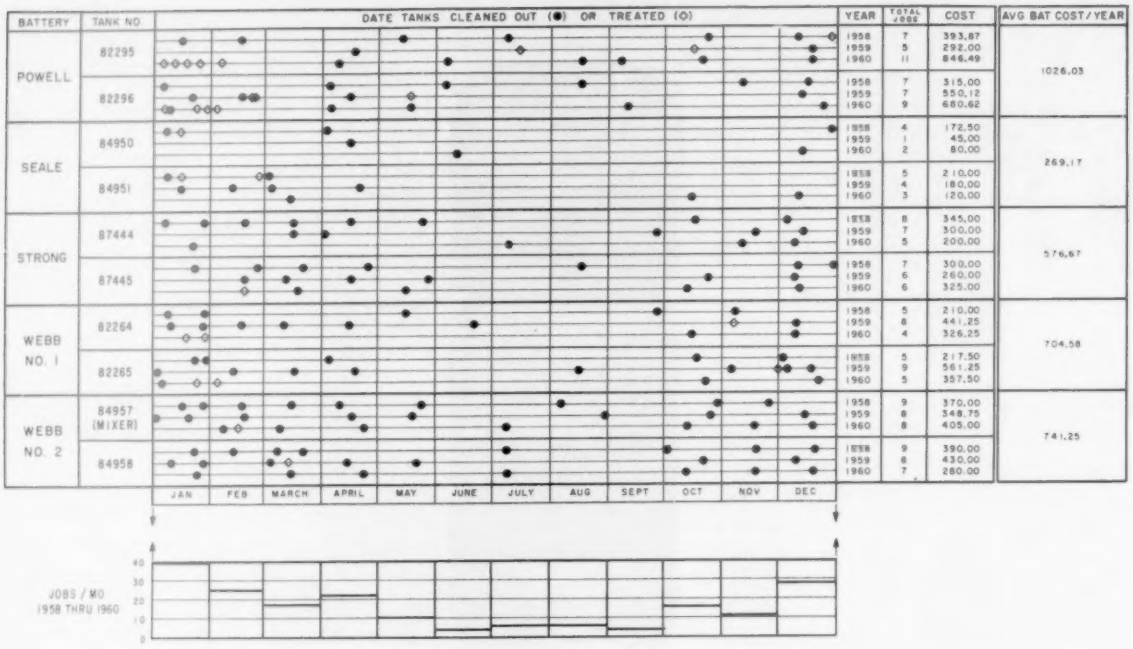
Table 2. Three-Year Daily Record of Stock Tank Cleanout — Treating and Costs West Seagraves Field Gaines and Yoakum Counties, Texas.



BS&W content measured 0.9%, eight times when the BS&W content was 0.8%, etc. Its companion tank not equipped with mixing equipment (Tank No. 84958) was emptied three times when the BS&W content measured 0.3%, and 20 times when BS&W was 0.2%.

It appears that an increase in BS&W of about 0.5% is the penalty for a mixer installation. However, this volume does not represent a production loss; it would be part of the bottoms had no mixer been used and eventually would be discarded.

API Gravity Changes

A check on the API gravities corrected to 60 F reflected very little change. API gravities of crude oil in both tanks varied between 36.3 and 36.8 deg. Because of these small oil gravity limits, the price per bbl of oil was not affected.

Mixer Installation

This propeller-type mixer consists of two segments: a tank unit and a drive unit. Each segment flanges together at the left of the ruler in Fig. 1. The drive shaft also separates at this juncture. The tank unit houses the variable angle feature which is similar to a ball and socket fitting and designed to permit movement of the manway entry angle through a 40-deg horizontal arc. Hinge on the cleanout plate supports the weight of both units.

The 1½-hp electric drive unit can be disconnected from the tank unit at the breakout flange. Gear ratio of the motor to the propeller shaft is about 4:1.

The entire assembly is located as near the tank bottom as possible. Electrical connections at the tank battery are explosion proof. A raintight fusible safety disconnect switch box mounted on a light pole provides manual on-and-off control. The switch can be sealed in the "on" or "off" position, a feature desired by the pipeline company.

The hinged mount for the mixing unit allows a sweep mixing action over the tank bottom. To utilize this feature to the fullest, the mixer is positioned to full left or full right 20 deg and straight ahead. In this manner, tank bottoms are prevented from piling up in any localized area.

This initial test installation and method of operation was so successful that changes were unnecessary during or following the test period.

Mixing Operations

Actual mixing operations commenced when the high 1000-bbl tank was filled to a little over half full (oil level between 9 and 12 ft). The mixer was rotated to the left 20 deg, straight ahead and then 20 deg to the right. At each position, the mixer was allowed to run for 24 hours. This procedure was continued until two hours prior to gaging the tank. At this time,

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FIG. 3. Rain-tight fusible safety disconnect switch box mounted on nearby pole provides manual "on-off" control. It can be sealed in the "on" or "off" position.

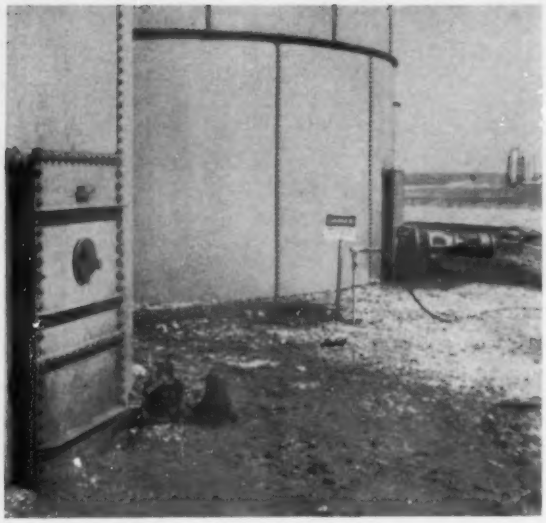


FIG. 4. Electrical conduit rises from ground on a line half the distance between the cleanout plates on two adjacent lease tanks.

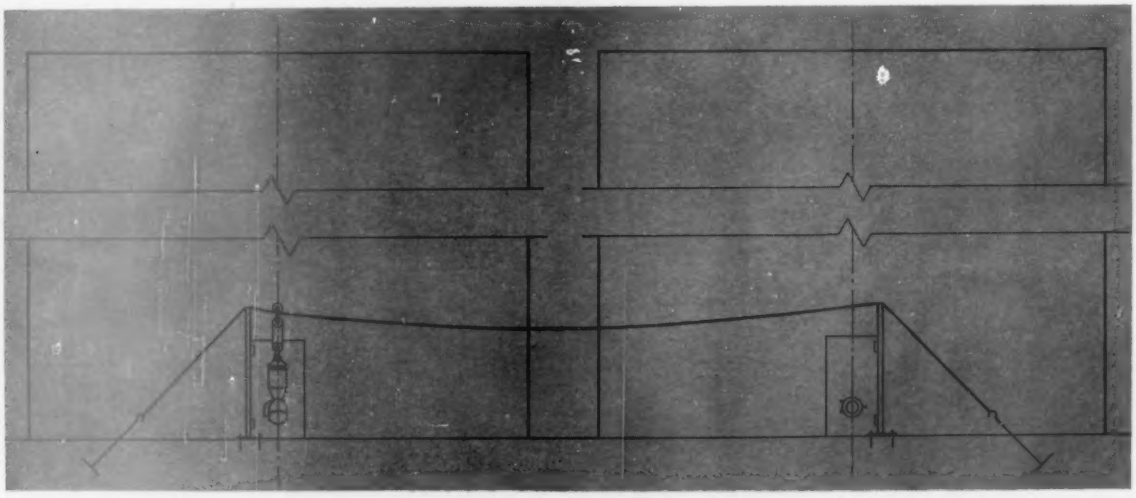


FIG. 5. Trolley design to transfer one power mixer drive unit weighing 170 lb from one lease tank to an adjacent tank. Idea saves the cost of one power unit.

the mixer was shut down to allow the oil level to settle.

Occasionally, the mixer was run only one day before turning the tank into the pipeline. It was never run more than four days of continuous service prior to shutting down before gaging the full tank.

Operating Costs

Cost of operating the 1½-hp electric motor driving the mixer at 100% load for an average of five days amounts to about $1.89 per month. Of course, the cost would double for a 2-tank battery where mixing is employed on both tanks. No normal maintenance was required on the test installation. During an electrical storm the motor was burned out and re-wound.

Table 2 shows the average annual cost to clean out and treat each of the five tank batteries in the West Seagraves field over a 3-year period. Since the tank with mixer required no special attention between March 15, 1960, and the end of the year, it assumed the cleanout frequency of its companion tank for purposes of payout.

This graph points out, on a per-tank basis, the type job performed at a specific time of the year. It also indicates the number of jobs and the cost per year for each of the 10 field stock tanks for the years 1958 through 1960, and the 3-year

average battery cost per year. The total field cost to maintain levels of the tank bottoms below the pipeline 8-in. maximum high bottom level averages $3317.70 per year.

At the bottom of Table 2 is a monthly plot of all jobs performed on all tanks. During the summer, when atmospheric temperatures are warmest, tank cleaning was held to a minimum but not completely eliminated. It is evident seasonal temperature changes play an important role in tank cleaning frequency.

Payout Calculations

This trial tank mixing hookup provided a method to eliminate stock tank bottoms. Assuming these results can be duplicated with additional installations on the remaining field tank batteries, an economic analysis was made. Values in Table 3 indicate a fairly attractive payout period averaging 2.03 years for all batteries except the Seale lease, where a mixer installation is not justified at this time. When Seale battery's one well ceases to flow (other wells pump relatively high water volumes), a tank mixer installation will be considered.

Electrical installation costs include labor and material to string 440-v electrical power systems to each tank mixer drive unit from available field transformers. Existing adequate transformers and underbuilding of installed power poles keep these costs nominal. Fig. 3 and 4 illustrate the electrical hookup required.

Table 3. Calculated Payout of Tank Mixing Installations in the West Seagraves Field (two tanks per battery).

Tank battery name	Electrical installation	Mixer installation	Labor & transportation	Average yearly cost	Estimated payout-years
Powell.....	($375	+ $1146	+ $100)	+ $1026.03 =	1.58
Seale.....	($590	+ $1146	+ $100)	+ $ 269.17 =	6.82
Strong.....	($251	+ $1146	+ $100)	+ $ 576.67 =	2.60
Webb No. 1...	($328	+ $1146	+ $100)	+ $ 704.58 =	2.23
Webb No. 2...	($299	+ $1146	+ $100)	+ $ 741.25 =	2.04

Mixer installation costs include one drive unit and two tank units per 2-tank battery. Since only one of the two high 1000-bbl tanks are filled at a time, one 170-lb electrical drive unit can be used to service both tanks at each battery. Fig. 5 illustrates how this trolley idea works to cut the number of required drive units in half. This hookup is fabricated largely from scrap material, thus saving the cost of one drive unit ($333) per battery. This drive unit design places the electric motor in a vertical position or at right angle to the tank unit when connected.

Miscellaneous labor and cost of transportation of material to the lease are estimated at $100 per battery.

The sum of all the cost items is divided by the average cost (three-year period) to clean tank bottoms from each battery. The result is the estimated payout period in years.

Application Factors

Feasibility of this type tank mixer installation depends largely on: (1) insufficient volumes of natural gas to roll tank bottoms or to fire heater-treaters; (2) ineffective results from chemical solvents containing some partial colloidal suspension properties; (3) high costs to maintain low tank bottoms; (4) satisfactory results from the use of chemical emulsion breakers; (5) low installation cost of electrical system; and (6) a reasonable payout period for each installation.

Another Step

At a time when the producer's dollar is under pressure from all quarters, savings in operating costs as are demonstrated here can make a substantial difference in profit and loss. This study indicates what cost-conscious field operating personnel can do and certainly represents another step in the right economic direction.

About the Author

George A. Savary is a petroleum engineer in the A-P Division of Union Texas Natural Gas Corporation at Midland, Texas. He obtained a BS in petroleum and natural gas engineering from Texas College of Arts and Industries, Kingsville, in 1955. Prior to entering college he worked for Texas Eastern Transmission Corporation in North Little Rock, Arkansas, as a junior gas measurement engineer. After college he was a roustabout for Texaco in Pampa, Texas, for one year before transferring to Texaco's foreign subsidiary, Texas Petroleum, in Venezuela. After three years of foreign duty he returned to the U. S. and joined Anderson-Prichard Oil Corporation in Midland, Texas. He is a member of the Society of Petroleum Engineers of AIME.

Acknowledgment

For permission to prepare and publish this report, the author wishes to thank the Union Texas Natural Gas Corporation, A-P Division (formerly Anderson-Prichard Oil Corporation), and the Jensen Engineering Company of Tulsa, Oklahoma, for their constructive help in this test installation.

■

PRECISION CONTROL

...THE ADDED BENEFIT IN HALLIBURTON BULK CEMENTING

As unforeseeable formation conditions have become more difficult in today's deep drilling, precision cementing control has become an absolute necessity. Halliburton provides this Precision Control in operations involving cement blending, mixing and pumping.

Accurate control of slurry weight is accomplished with instruments such as the Halliburton Densometer and Densitroller. Control of handling and pumping the cement belongs to the modern Halliburton Cementing Equipment. Downhole, special Halliburton tools carry precision control through to the cementing target — formations needing protection. All of these control techniques have been pioneered by Halliburton in the performance of over three million service jobs during the past three decades.

This precision cementing capability is exercised by your Halliburton Cementer. He knows how to use the tools, machines, and materials to help you get the very best results possible from your cementing job.

Some Halliburton methods for providing Precision Cementing Control...

OF SLURRY DENSITY

POZMIX CEMENT provides a more economical light-weight slurry that gives more fill-up per sack, pumps easily, and perforates with less shattering. Natural or artificial pozzolans used in this slurry react with the free calcium hydroxide released when portland cement hydrates . . . increasing resistance to sulfate attack.

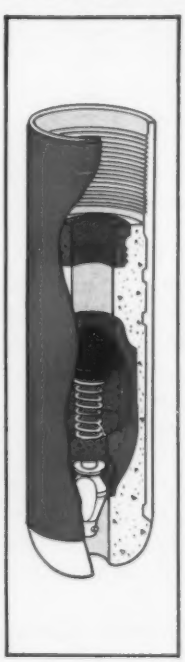
OF SETTING TIME

HALLIBURTON HA-5 improved cement accelerator reduces waiting-on-cement time in shallow wells or on surface pipe. Adding low concentrations of HA-5 to dry cement or mixing water reduces the WOC time to four to eight hours, depending on temperature, cementing composition and strength desired at the time of drilling out.

OF FLUID LOSS

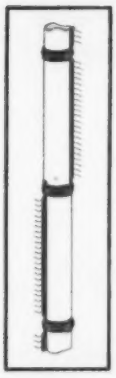
HALLIBURTON HALAD-9 controls fluid loss of cementing compositions to increase efficiency in primary and squeeze cementing. Sustained heat stability under extreme bottom-hole temperatures provides an advantage in hesitation squeeze techniques.

WITH MODERN TOOLS



AUTOMATIC FILL-UP SUPER SEAL FLOATING EQUIPMENT eliminates frequent stops for manual filling of casing — saving rig time. Carefully-calculated orifices in the fill-up attachment permit control of fluid flow into the string. An orifice sleeve attached to the Super Seal valve stem holds the valve off its seat, permitting filling.

Increasing pressure from a conventional rig pump at any time shears a pin and allows the spring-operated Super Seal back pressure valve to close and help float casing to desired hole depth. All internal parts are drillable. Halliburton Automatic Fill-Up Super Seal Float Shoes and Float Collars are available for all standard casing and tubing sizes.



HALLIBURTON ROTO WALL CLEANERS remove mud cake from the borehole wall . . . provide a better cement bond and minimize squeeze cementing jobs. This easy-to-install cleaner causes less mud cake disturbance while running casing and operates only in the zones where needed. Coiled springs inside the cleaner base protect spikes from damage while running-in and rotating to remove unwanted mud cake. Roto Wall Cleaners are available to meet all specifications — including slim hole sizes.

HALLIBURTON S-3 CENTRALIZER centers to secure uniform cementing on all sides of the casing for a better cement bond . . . even in greatly deviated hole. Clearance between the centralizer's end bands and the casing permits free rotation of the casing. The centralizer's 28-in. long heat-treated steel springs cover adequate sidewall to avoid key seats. Open spring spacing provides free fluid flow.

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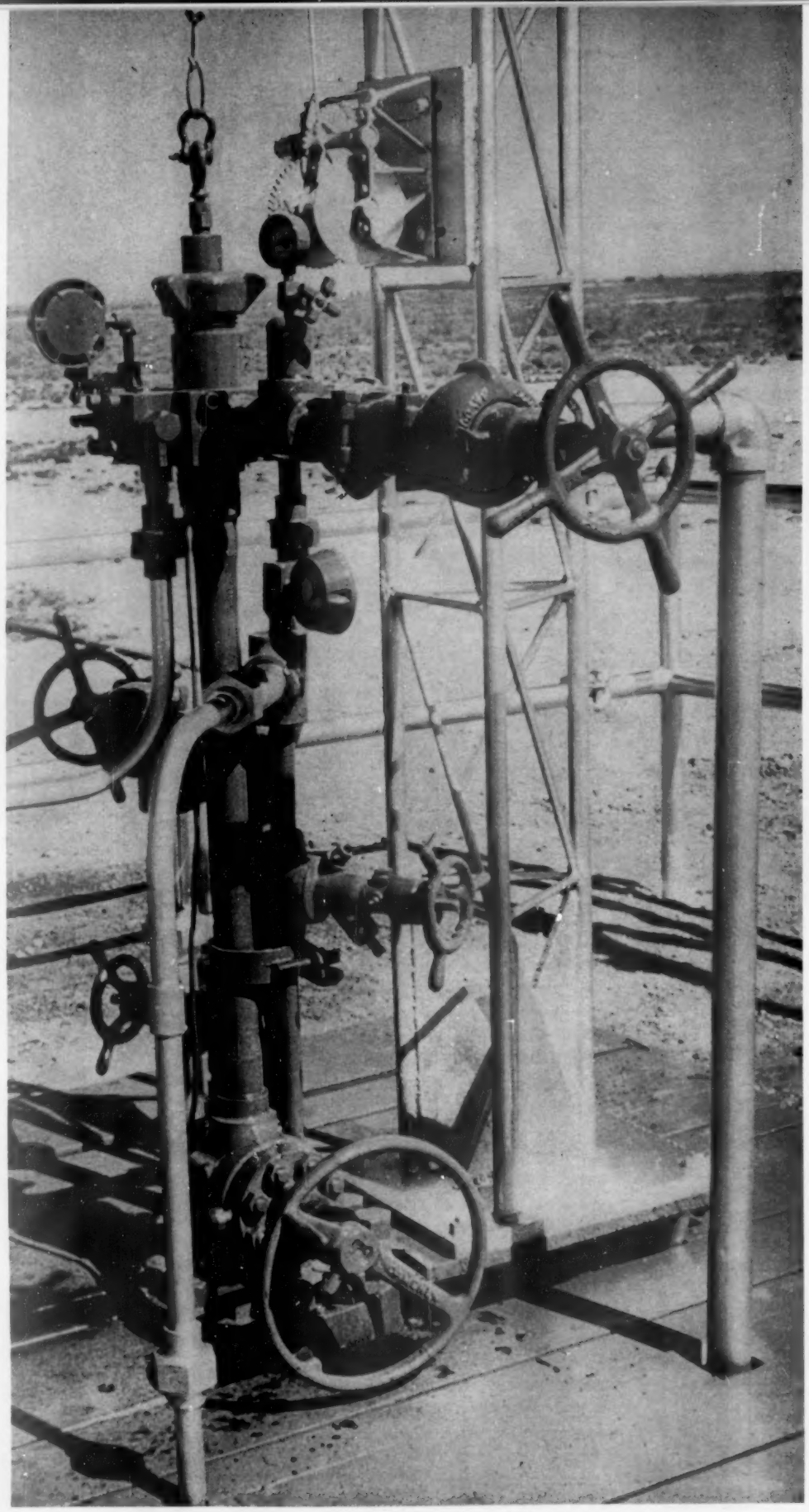


Triple completion tree for dual hydraulic pump installation in West Texas. Base of 30-ft structural mast shown in background. This mast with hand winch permits one-man operation to change tandem free-type pumps.

by Bob G. Murphy

Lifting Larger Volumes From Deep Duals

A unique dual completion program to artificially lift increasing fluid volumes from five existing wells in West Texas has been devised by Cities Service Petroleum Company. Free type tandem dual hydraulic pumps set inside 5½-in. OD casing simultaneously pump both zones.

The wells are in the Goldsmith field of Ector County. The upper zone is the Fusselman located at around 8300 ft; the lower zone, the Ellenberger, at about 9450 ft. The wells originally flowed, until increased water production forced artificial lift considerations if both reservoirs were to be depleted economically.

Cities Service engineers had to consider: producing depths; fluid withdrawal rates; use of surface and subsurface equipment; future downhole equipment maintenance; casing sizes; and clearance problems in the case of dual or triple tubing strings.

The tandem pumps are set at about 8000 ft in the 5½-in. OD 17-lb casing, using one string of 2⅜-in. OD EUE tubing and two parallel strings of 1.315-in. OD integral joint tubing with a coupling OD of 1.552 in. Clearance of the three strings inside the 5½-in. casing was of prime consideration. Fig. 1 shows the geometry of the tubing collar and joint outside diameters in relation to the casing ID which had a drift diameter of 4.767 in.

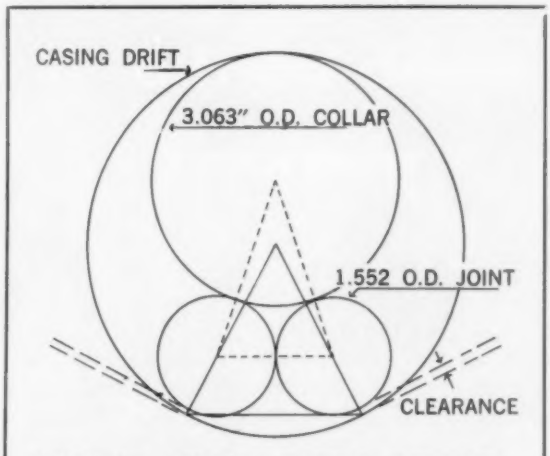
Experience indicated that collars of the 2⅜-in. OD tubing should be bevelled to permit ease of pulling the two smaller strings from the well.

Running Subsurface Equipment

First step involves running and setting the permanent-type production packer located just above the lower producing zone. The bottom hole assembly then is run in on the 2⅜-in. tubing string, the bottom of which is a perforated joint equipped with a tubing seal assembly for the lower zone packer. The upper packer is a full opening snap-set type and is assembled on the 2⅜-in. string on the surface. In the main tubing string immediately below this upper packer is a side-door choke. Its purpose is to facilitate formation stimulation of the upper zone should this or other treatment become necessary.

The bottom-hole assembly includes a seating shoe for the retrievable standing valve, landing shoes for the two parallel macaroni (small 1.315-in. OD) strings and seal sleeves for the various seals required between the tandem hydraulic units and the bottom-hole assembly.

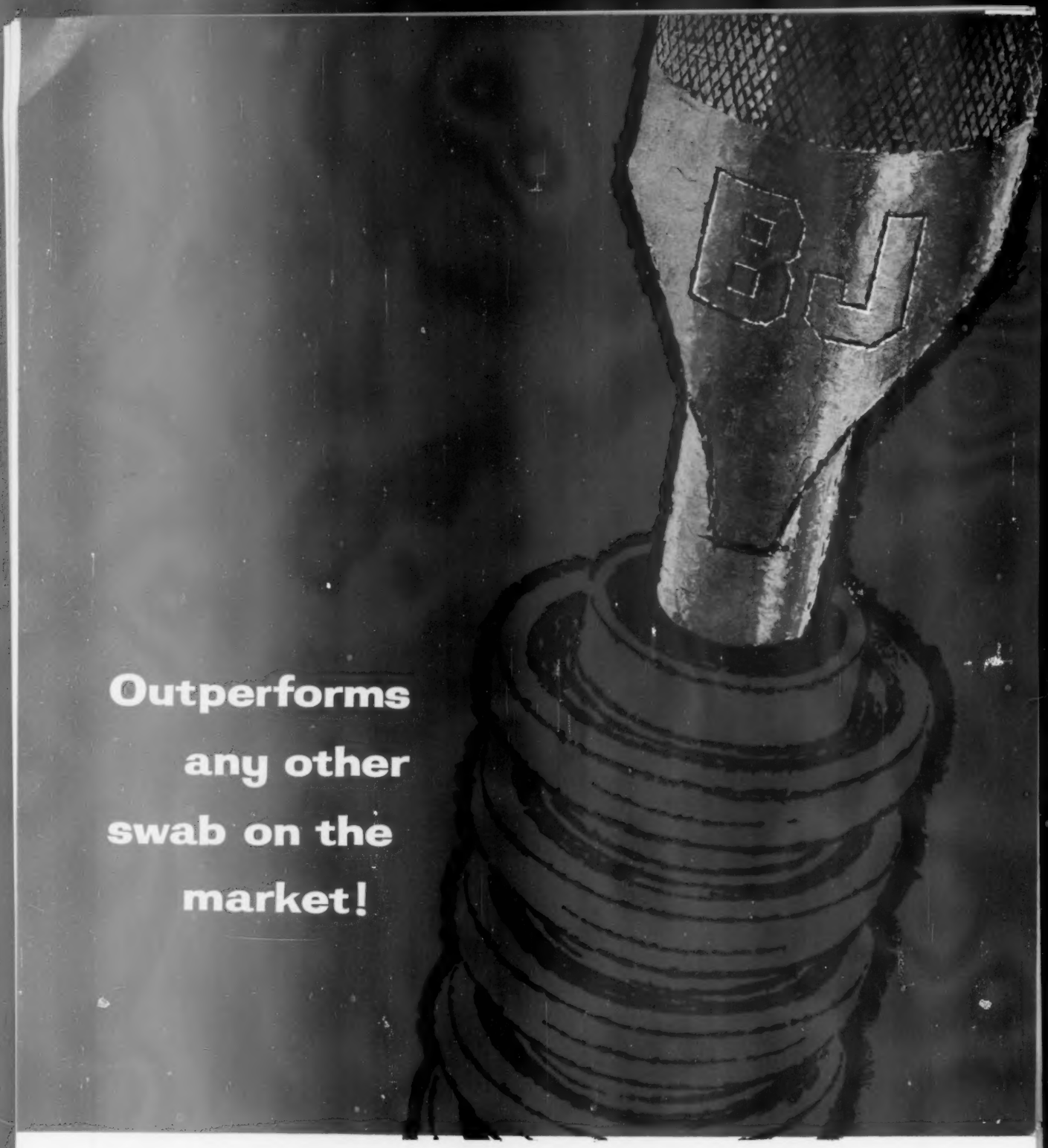
In running the subsurface equipment, the



CASING OD	WEIGHT LB/FT	DRIFT-ID	CLEARANCE INCHES
5½	15.50	4.825	0.104
5½	15.50*	4.653	0.018
5½	17.00	4.767	0.075
5½	20.00	4.653	0.018

*EXTREME LINE

FIG. 1. Casing clearance of the three strings inside 5½-in. casing for three different pipe weights show critical problem.



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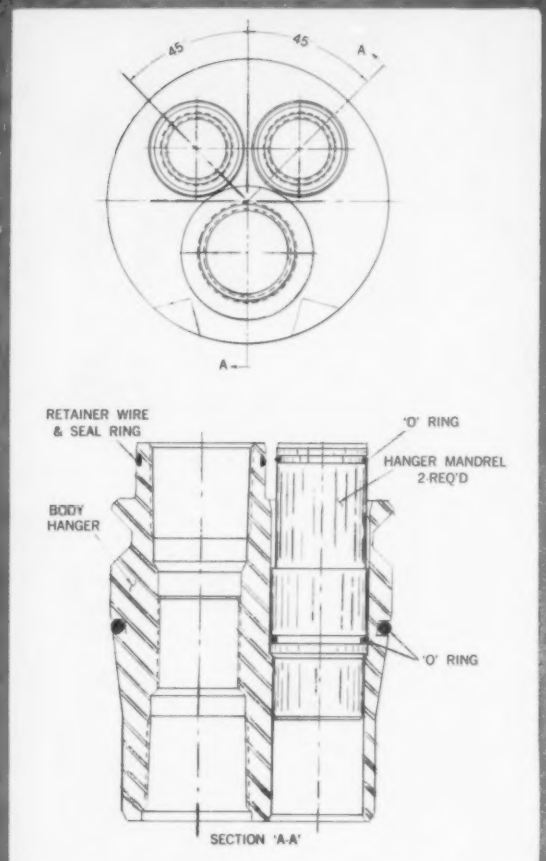


FIG. 2. Special donut flange and tubing hanger designed for the three-string completion in this dual hydraulic pump installation. (Courtesy Cameron Iron Works. Houston, Texas.)

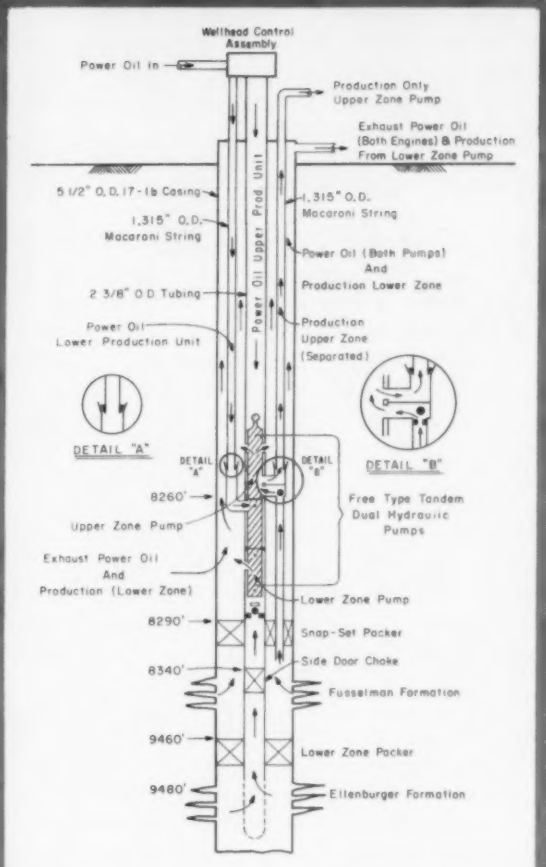


FIG. 3. Basic completion and fluid flow in dual zone hydraulic pump completion. Tandem pump assembly can be pumped to surface when desired.

bottom-hole assembly is made up on the upper packer with a stinger for the upper pump suction connected into the landing shoe and extending through the packer. This assembly then is run in the hole on the large tubing string which is landed in the lower production packer. Fig. 3 and 4 are schematic diagrams of the subsurface installation in relation to the component parts.

A specially-made offset type triple "donut" hanger is used to land the $2\frac{3}{8}$-in. main string in the tubing head. See Fig. 2. To assure well control during running the main tubing string with bottom-hole assembly attached and subsequent macaroni strings, a blowout preventer containing 2-in. regular and offset rams as well as 1-in. offset and blind rams is used.

Each of the two 1.315-in. OD macaroni strings equipped with integral joints are run into the well independently and landed in the landing collar in the bottom-hole assembly. The landing spear which is made up on the upper pump production return string includes the suction standing valve for the upper pump. The spear is landed in the pump cavity shoe with a small (1500 to 2000 lb) amount of applied tubing weight. This landing spear is furnished with a friction ring which insures seating it in the shoe. About the same pull (1500-2000 lb) above tubing weight is required to unseat the spear. Construction of the spear insures positive pressure balance between the seals, and eliminates unseating forces on the parallel strings.

After the spear is seated, the 1.315-in. OD macaroni string is landed with a small mandrel in the special triple "donut" hanger in the well head. The second 1.315-in. OD parallel macaroni string and spear are run in the same manner and seated. The landing spear which is made up on the upper pump production return string includes the suction standing valve for the upper

pump. A specially-made triple string tree is nippled to the well head to complete the well installation. The manner in which both macaroni strings are run insures proper seating of each string in the desired landing shoe receptacle of the bottom-hole assembly.

How Installation Works

Operating principle of the installation can be explained by referring to Fig. 2. Essentially there are four means of down-hole communication with the surface: (1) a single 2⅜-in. OD N-80 main tubing string; (2) casing annulus; (3 and 4) two 1.315-in. OD macaroni strings. Power oil for the hydraulic unit on the upper zone is carried down the main tubing string. The lower zone unit is powered by oil pumped down one of the macaroni strings (at left of Fig. 2). Production from the upper zone is separated and pumped up the other (right of Fig. 2) macaroni string. Power oil exhaust from both upper and lower zone pumps discharges into the casing annulus along with fluid production from the upper zone.

Fig. 3 illustrates the bottom-hole pump cavity and landing shoe with the dual tandem hydraulic units and landing spears in place. This diagram shows how the pump cavity and landing shoe is run on the main 2⅜-in. OD tubing string above the snap-set packer and connected to the parallel side of the packer with a short piece of 1.315-in. OD tubing.

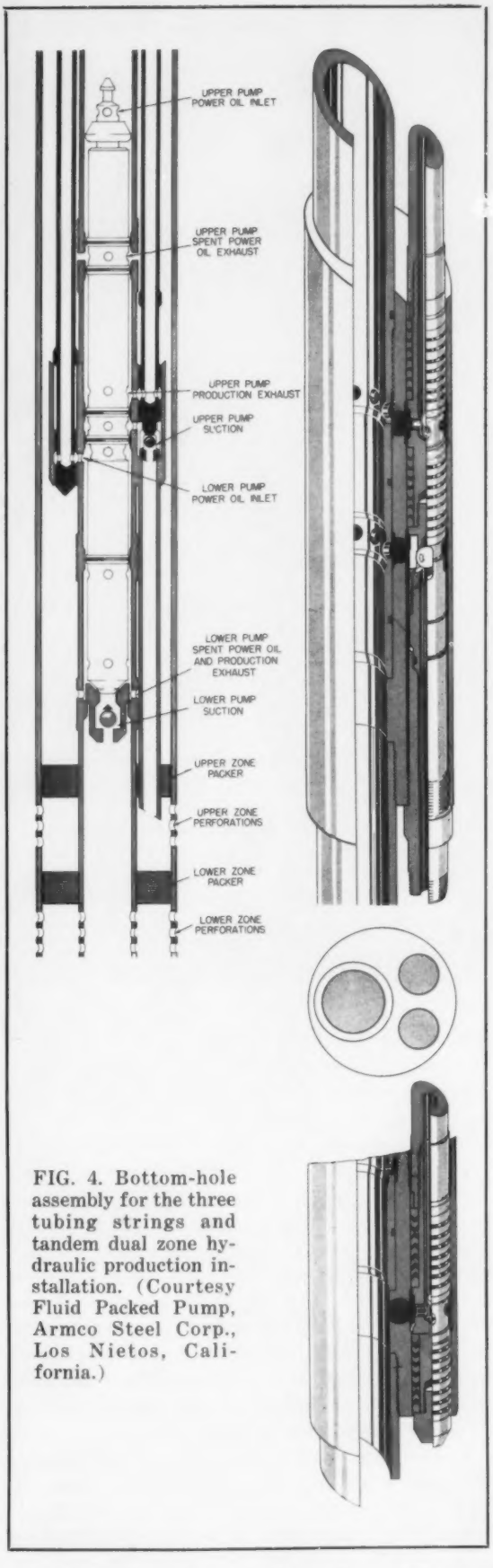
The upper pump takes suction from the upper zone through the upper packer and the macaroni string between the upper packer and crossover. A standing valve in the 1.315-in. OD string prevents flooding the upper zone while the two pumps are pumped out of cavity.

The lower pump takes suction through a wireline retrievable standing valve in the 2⅜-in. OD tubing string from the lower zone. Production is exhausted into the casing annulus.

The lower producing zone is the source of the common power oil while the upper zone production remains isolated. Only one surface power oil system is required to operate both pumps.

The lower zone was chosen for the power oil source because it produces cleaner oil relatively free of paraffin. The top 2500 ft of the upper zone macaroni production string was plastic coated to control paraffin deposition.

Both hydraulic pumps are two "free type" production units joined together and run "piggy-back" style inside the main tubing string. The two pumps are physically connected with a center seal and starting filter assembly for ease of installation. But they are entirely separated in their hydraulic circuits. Operating pressure of


UPPER PUMP POWER OIL INLET
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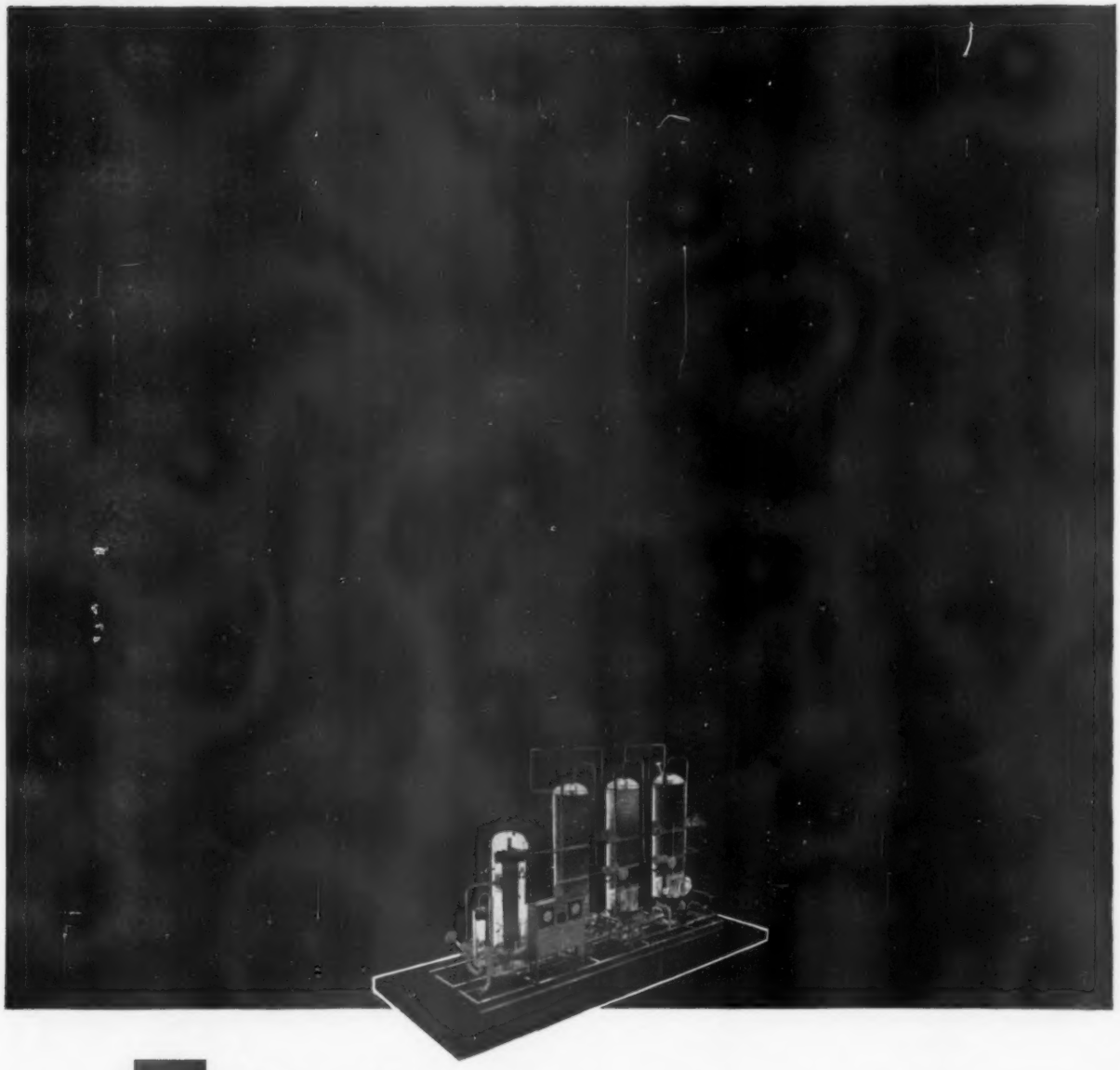
LOWER PUMP SUCTION
UPPER ZONE PACKER
UPPER ZONE PERFORATIONS
LOWER ZONE PACKER
LOWER ZONE PERFORATIONS

FIG. 4. Bottom-hole assembly for the three tubing strings and tandem dual zone hydraulic production installation. (Courtesy Fluid Packed Pump, Armco Steel Corp., Los Nietos, California.)



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That's what Parkersburg means by *Dynamic Adsorption* . . . keeping the dessicant *active* through frequent cycles: adsorption, regeneration by controlled heat, then cooling prior to further adsorption. The benefit to you is the *extra* hydrocarbon product adsorbed, removed and condensed by Dynamic Adsorption. As an extra bonus, gas is dehydrated to pipeline specifications.

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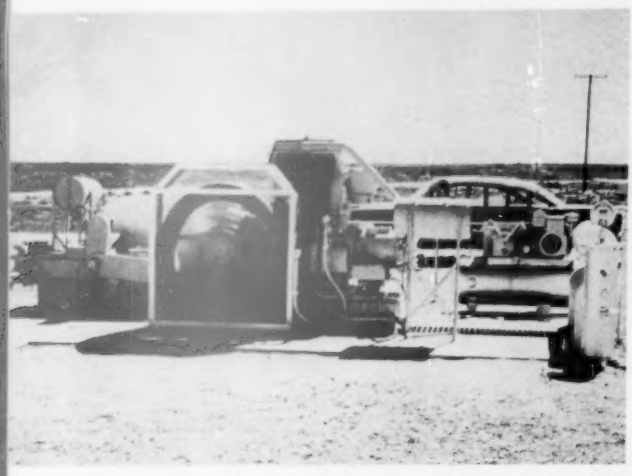
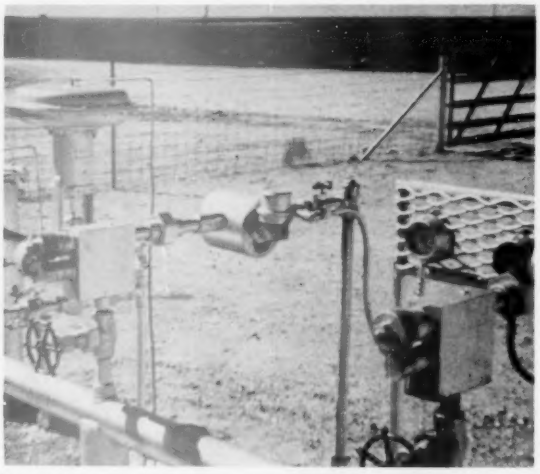


Power unit for single well furnishing from 2000 to 3000 psi power oil consists of a 60-hp single-cylinder gas engine driving a triplex pump rated at 50-hp input.



Metering manifold on high-pressure power oil line maintains a constant power oil pressure and constant flow.

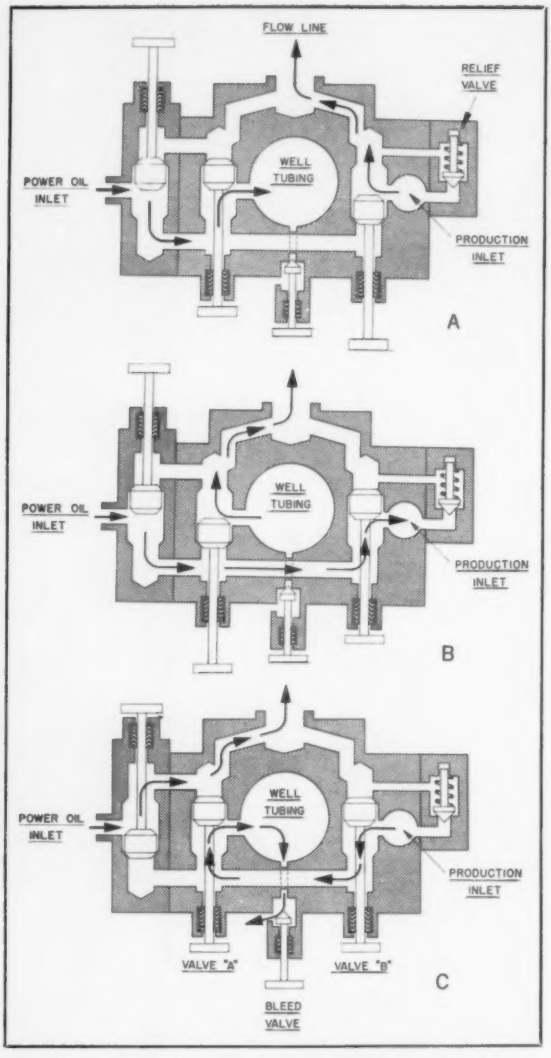


FIG. 5. Wellhead control assembly directs fluid flow of power oil into the well and flow of production from one macaroni string (upper zone). (A) Pump in and operate. (B) Pump out. (C) By-pass and bleed.

the power oil supply system is from 2000 to 3000 psi, but actual operating pressure is a function of fluid levels and/or productivity index.

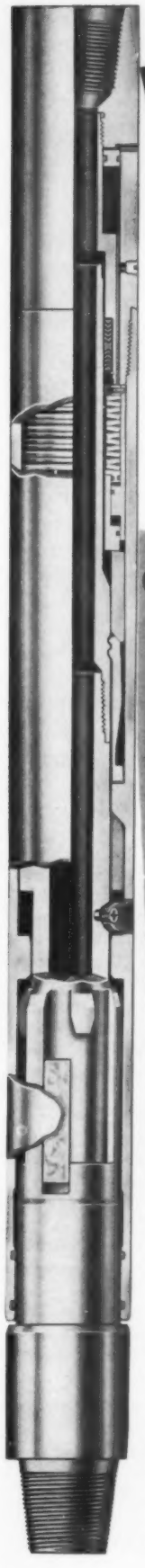
Fluid production from each zone is kept separated in this installation. However, it is necessary to commingle the exhaust power oil from both engines with fluid production from the lower zone.

Seals throughout the cavity are rubber O-rings and teflon back-up rings. The pump assembly is equipped with swab cups to permit the "piggy-back" unit to be pumped in and out of the 2⅜-in. OD tubing string. A catcher is located in a wellhead control assembly at the surface to retain the pumps when they are pumped up the tubing. A 30-ft structural tower was erected at the wellhead to facilitate installation and removal of the tandem pumps. One operator using a hand winch on the base of the tower can run or remove the tandem pump units which when connected as one assembly measure about 25 ft in length.

Free Type Pump

Fluid levels and withdrawal rates determine pump design. Tandem pumps selected are of the "free" type and of the proper size to run inside 2⅜-in. OD API EUE tubing. Pumps chosen for these installations are of balanced design, with a 1:1 ratio (power oil volume to fluid volume pumped), and capable of pumping 268 bbl per day at 100% operating efficiency.

One zone may be shut in while the other is pumped. Should one zone become capable of flowing while it is necessary to pump the other zone, a dummy pump can be run for that particular



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THE SHAFFER "HYDRAULIC TRIP" JAR SAFETY JOINT

Positive "3-In-1" Protection Is A Major Advancement In Fishing Tool Design

Again Shaffer brings a major new oil tool advancement to the oil industry, a "3-In-1" Fishing Jar that combines, in one tool, the protection of a "Hydraulic Trip" Straight-Pull Jar . . . plus the protection of a *Mechanical* Trip "Standby"... plus the controlled releasing action of a positive Safety Joint in the event the fish cannot be loosened and it is desired to release the fishing string.

Never before has a single tool combining such a wide range of safety features been available to the oil industry!

1 USED AS A HYDRAULIC JAR

Normally used as a straight-pull "Hydraulic Trip" Jar, this new Shaffer tool permits the force of each blow to be easily controlled at the surface. The operator simply takes a pull on the fishing string. This pull, acting through a built-in hydraulic chamber, causes the desired blow to be struck as soon as sufficient fluid passes through an orifice in the tool—a matter of only a few seconds between the time the pull is taken and the blow is struck.

- The tool re-sets itself automatically when the string is lowered, and repeated blows can be struck by simply raising and lowering the string!
- No torque is required—either to strike the blow or to re-set the tool!
- The force of the blow can be easily controlled by noting the amount of pull registered on the weight indicator. To strike a heavier blow, merely increase pull. To reduce blow, take less pull. *It's that simple!*
- Once the desired pull has been determined, the entire operating sequence can be timed by the driller so there is no loss of time while tripping or re-setting the tool!

2 MECHANICAL TRIP STANDBY

If for any reason the "Hydraulic Trip" should fail to function, a simple manipulation of the run-in string by-passes the hydraulic system so that the tool can be operated *mechanically*. This is a marked improvement over other hydraulic Jars which become inoperative should the hydraulic system fail!

3 POSITIVE SAFETY JOINT RELEASE

Still another unique feature is the built-in Safety Joint in the lower portion of the tool. If the fish cannot be loosened, and it is desired to release the run-in string, simply trip the tool and apply left-hand torque as the string is slowly lowered. This rotates locking lugs into releasing slots so that the string and a major portion of the tool itself can be recovered. The recovered portion of the Shaffer "Hydraulic Trip" Jar Safety Joint can then be used at the bottom of any subsequent fishing string to simplify reconnection with the fish!

Ample Bore Diameter: So that wire line equipment can pass freely through the "Hydraulic Trip" Jar Safety Joint, it has been designed with a generous bore throughout its length. For example, the 5¾ O.D. tool has a full 2" bore!

Fully Oil-Sealed: To prevent abrasive mud, sand or corrosive well fluids contacting the mechanism, all operating parts of the Shaffer "Hydraulic Trip" Jar Safety Joint are completely sealed in oil!

(Left) **The Shaffer "Hydraulic Trip" Jar Safety Joint in "Set" Position**

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zone to serve as a cross-over unit. For example, should the lower zone develop sufficient bottom-hole pressure to flow, a dummy pump could be run on bottom with communication between the engine and pump end. This arrangement would convert the former 1.315-in. OD macaroni power oil string into a lower zone production string. This string could be circulated with clear power oil and swabbed in if necessary to kick off the lower zone. This is actually the case in one Cities Service well equipped with this type installation.

Special Equipment

The down-hole pump cavity and shoe which is the first of this exact design to be installed inside 5½-in. OD casing required a triple tree that would accommodate one string of 2⅜-in. OD EUE API tubing and two strings of 1.315-in. OD integral joint tubing.

The first problem was to design a donut tubing hanger that would fit a 6-in. tubing hanger housing and support all three strings (see Fig. 2). This was solved by building a donut with a threaded 2⅜-in. EUE offset opening top and bottom and two 1.315-in. recessed offset openings. The offset donut hanger is made up on the 2⅜-in. OD string and landed. The 1.315-in. OD macaroni strings are run independently through the recessed offset openings and landed with small mandrels in the large "donut" and sealed with O-rings.

A triple 6-in. flange with one 2⅜-in. seal sub and two 1.315-in. seal subs is bolted to the hanger flange. On top of this flange a 2⅜-in. threaded EUE double recessed body valve controls the main string and two 1.315-in. EUE recessed body valves control the small parallel strings.

Surface Equipment

Surface equipment employed is similar to most hydraulic pump installations. It consists of a power oil tank, a triplex pump, prime mover, and the necessary header parts and valves to make the system complete and effective. Fig. 5 demonstrates how the flow of power oil is controlled. Since two pumps are operated at different pressures from a single header, pressure compensated valves of constant flow controllers prevent the pump operated at the lower pressure from taking more power oil than needed to operate it at the desired speed.

Pumping Efficiency

When pumping from under a packer with this type hydraulic unit, it was found that the higher the percentage of water to total fluid pumped, the higher the pumping efficiency. On the other hand, pumping efficiency was lowered as gas in solution increased.

Table 1. Performance Test Summary on One Dual Pump Installation in West Texas.

Test Number	Oil Bbl	Water Bbl	Efficiency Percent
Upper Zone Pump (1⅞-in. x 1.3-in. x 1.3-in.). Set @ 8275 ft			
1	91	151	86
2	58	204	98
3	46	75	69
Lower Zone Pump (same size as upper zone pump). Set @ 8290 ft			
1	123	0	57
2	83	19	57
3	70	4	42*

*Pump operating at 60% rated speed.

That both pumps can be pumped in and out of the well with equipment at the wellhead provides a definite maintenance advantage. Separate operation of both hydraulic units also proves desirable. Over production from one zone will not force an under-produced zone to be shut in prematurely. Flexibility of operations makes it possible to flow one zone simultaneously while artificially lifting the second zone of a dual completion. No major equipment changes are needed to reverse the production hookup.

About the Author

Bob G. Murphy is a production engineer for Cities Service Petroleum Company at Shreveport, Louisiana, having recently transferred from the company's Odessa, Texas, office. A Korean War veteran, and registered professional engineer, he was graduated in 1950 from Oklahoma A&M College with a BS degree in commerce and in 1956 with a BS degree in industrial engineering and management from Oklahoma Institute of Technology. While attending OIT, he worked with Lane Wells Company as a perforating gun loader. Upon graduaton he was promoted to division engineer. In 1957, he joined Cities Service at Russell, Kansas, as a production engineer, and in 1959 was transferred to Odessa, where he concentrated on single and dual zone completion techniques, and the design and installation of waterflood plants.

Acknowledgment

Based on a paper given by the author at the Eighth Annual West Texas Oil Lifting Short Course at Texas Technological College, Lubbock, Texas, April 20-21, 1961.

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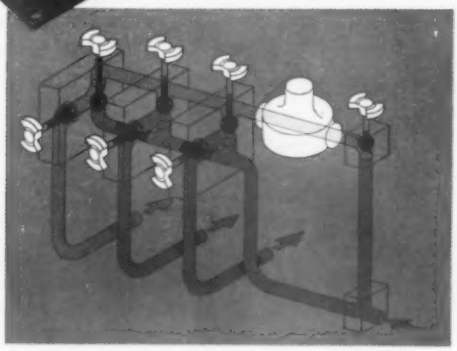
HYDRAULIC PUMPING CONTROL MANIFOLD

"BUILDING BLOCKS" offer... Simplicity, Flexibility, Economy



Simplicity and Flexibility mean Economy with the new Oilmaster concept for Central Power Control Manifolds. Previously, hydraulic pumping systems required a maze of manifold plumbing to direct and control the rate of power oil flow to individual wells. Oilmaster has refined this plumbing maze to a simplified "building block" control system which is more efficient and easier to operate. This control system is built around well control stations, each having internal valves and ports for power oil distribution and control. One control station is included in the manifold for each well in the system. The manifold also includes the flow meter that allows selective metering of any well in the system. This "building block" design facilitates assembly and installation of Central Power Control Manifolds.

The block construction simplifies the control operation by permitting rapid switching to the meter header without interrupting the controlled flow of power oil to each well. Individual well control blocks are joined by flanged connecting spools which form continuous power oil passages to each block. Additional wells can be added to the manifold with minimum effort and cost... and the manifold or any component is salvable for moving to other installations.

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ARMCO Fluid Packed Pump

by Gordon E. Taylor

Quadruple Completion Made Inside 5½-in. Casing

An unusual quadruple completion in the Boonsville Bend field of Wise County, Texas, has cut over $21,000 from the cost of two dual wells and leaves the door open for future well work without disturbing the completion.

Christie, Mitchell & Mitchell Co., of Houston, Texas, has completed two quadruples thus far in the North Texas field between depths of approximately 4000 to 5700 ft inside 5½-in. OD casing. Three upper strings of 1.660-in. OD tubing were used, with the center string placed inside 2⅞-in. OD tubing between the upper two retainer packers. Zones common to both wells include three gas reservoirs and one oil reservoir. Oil production is in the lower producing zone.

The two wells are CM&M's No. 1 Methodist Youth Camp and its No. 2 Paul Curtner. Since the completion program on both wells is identical, only the Methodist Youth Camp well is described. It is illustrated in Fig. 1.

In the future, CM&M can test and low-pressure treat each of the individual four zones, make bottom-hole pressure surveys, and can treat with hot oil for paraffin removal without interfering with the completion.

Fig. 2 illustrates a portion of the electric log from CM&M's No. 1 Methodist Youth Camp showing the four producing zones. Vertical black bars indicate the perforated interval in each zone. Upper productive interval is the 4000-ft Strawn which makes up the Morris field. It produces associated gas at a calculated absolute open flow rate of 1250 Mcf per day. Allowable is 186 Mcf per day, based on oil producing day schedules. Productive interval referred to as the 1-C zone is from 4005 to 4028 ft.

The second productive horizon is the 4300-ft Strawn sand which also is part of the Morris field. It is a non-associated gas reservoir with a calculated absolute open flow of 460 Mcf per day. Non-prorated allowable is 115 Mcf per day. It is called the 1-UT zone and is perforated from 4274 to 4295 ft.

Thinnest of all horizons is the 1-MT zone which is a Bend conglomerate of the Atoka conglomerate series. It is also a non-associated gas reservoir perforated from 5272 to 5276 ft. Calculated absolute open flow is 1550 Mcf per day. Allowable based on acreage multiplied by bottom-hole pressure averages 500 Mcf per day. This Pennsylvanian reservoir makes up the Boonsville field.

The bottom horizon produces oil from the 5400-ft conglomerate of Pennsylvanian age. It is part of the Morris field. Prorated production is 82 bbl of oil per day. Potential test of this horizon perforated from 5413 to 5434 ft gaged 143 bbl per day of 42.3 API gravity oil through a 16/64-in. choke with a tubing pressure of 200 psig. Gas-oil ratio was 1024 cu ft per bbl.

Production Flow Pattern

Fig. 3 shows the flow paths of all four zones into the well bore and up the individual tubing strings. The upper gas zone flows directly into the casing annulus as indicated.

Gas production from the second zone, the 4300-ft Strawn, flows into the casing beneath the top packer. This gas is conducted through the bottom of a flow tube into one of the 1.660-in. OD macaroni tubing strings (right string in Fig. 3).

The lower gas zone, or third horizon, produces into the casing between the second and third packer. This gas flows up through the annulus of the concentric string which is hung from the flow tube on the top packer. Flow goes through

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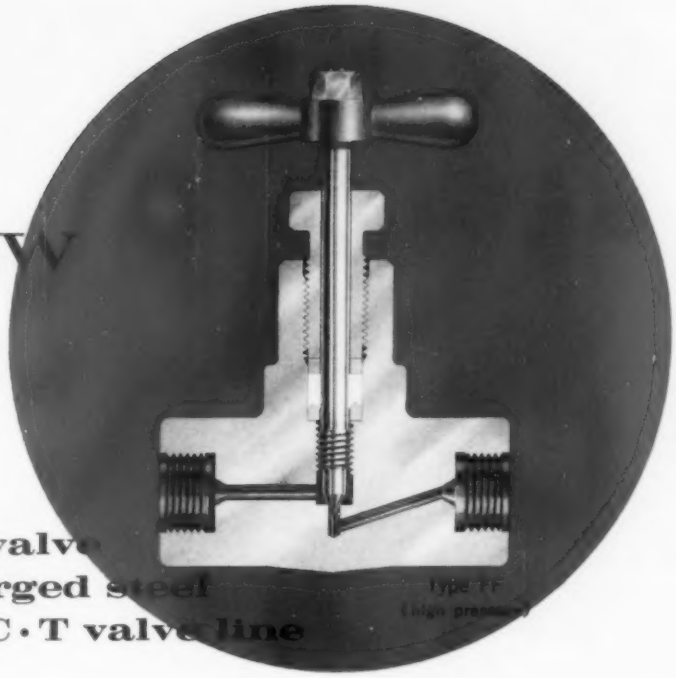

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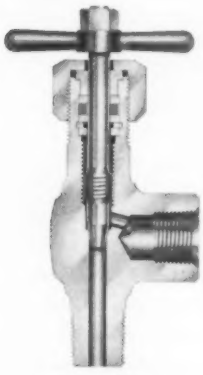

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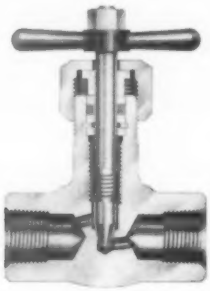

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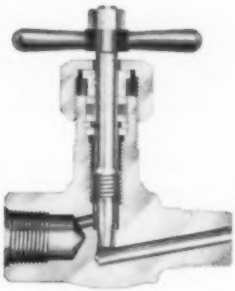

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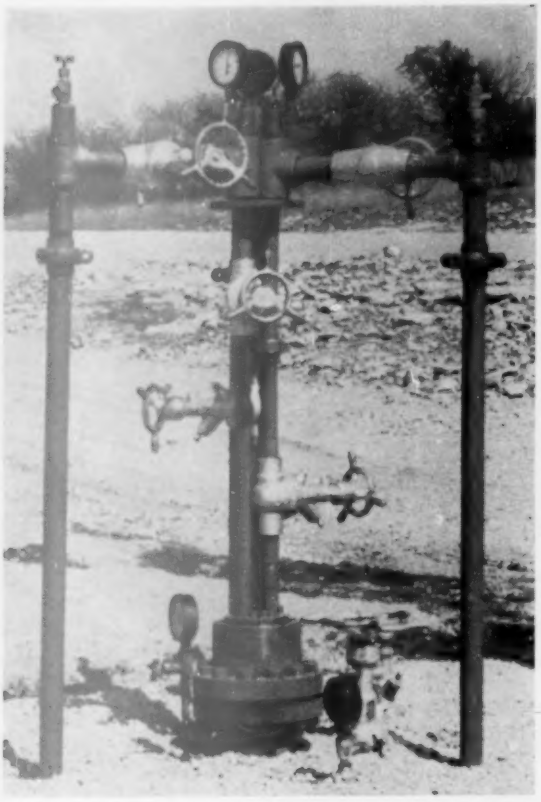

Triple string tree on Christie, Mitchell & Mitchell Company's No. 1 Methodist Youth Camp quadruple producer in the Boonsville Bend field of Wise County in North Texas. Casing annulus conducts production from upper gas zone.

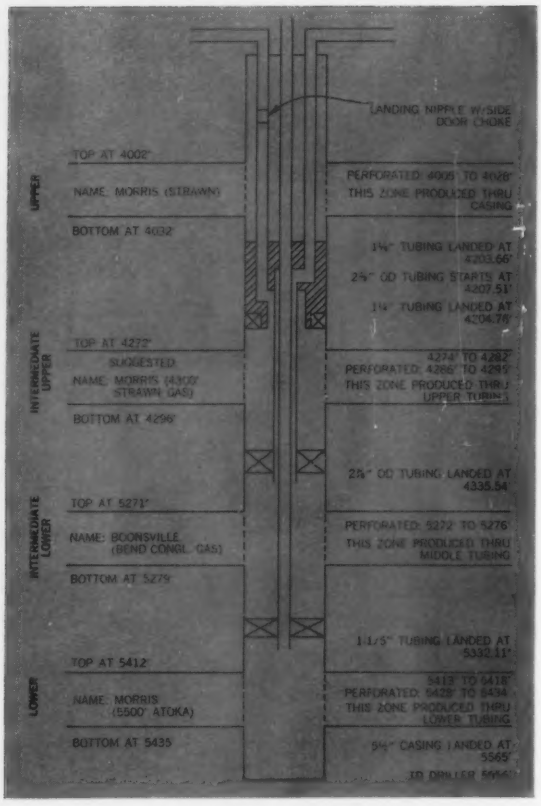

Fig. 1. Quadruple completion diagram shows relationship of major components of down-hole equipment and their position in the well. All four zones flow naturally. Upper three horizons are gas; lower reservoir is oil.

the flow tube and into the macaroni string on the left in Fig. 3.

The bottom oil zone, which also flows, enters the well bore below the bottom packer. Production is through a perforated production tube and up into the primary tubing string shown schematically in Fig. 3 as the center string.

Down-Hole Completion Equipment

Down-hole completion equipment consists of three retainer-type packers, accessory seals, triple-string flow tube and auxiliary items. Major equipment items are shown in their relative positions in the schematic diagram of Fig. 3. Bore size is the only difference in the packers. The triple-string flow tube is not a part of the upper packer. It serves to land and seat the three 1.660-in. OD macaroni's strings. The lower part of this flow tube seals off in the top bore of the upper retainer-type packer as shown in Fig. 3.

A concentric tubing string 127 ft long connects the flow tube with the middle packer. The center macaroni string connects from the bottom of the triple-string flow tube (middle string of Fig. 3) and extends to and seats in the bottom packer. This center macaroni string is inside 2⅞-in. OD intermediate string, the bottom of which contains the seals for the middle packer.

This flow tube assembly is run in the well, connected to these two strings of tubing and equipped with necessary seals. When it lands in the top packer, seals for the middle and bottom packer are automatically positioned by predetermining setting depths of the packers and spacing out the tubing and seals accordingly.

After the flow tube is positioned in the top packer, the second and third strings of macaroni tubing equipped with seals on bottom are run and landed in the flow tube. This completes the isolation of the bottom three zones.

To make sure that the seals on the second and third strings are landed in the proper sealing bore, the seal on the second string of macaroni tubing is of a larger outside diameter than the seal on the third string of tubing. This feature is a part of the specific design of the flow tube and makes it impossible to seat these tubing strings in other than the bore for which they were designed.

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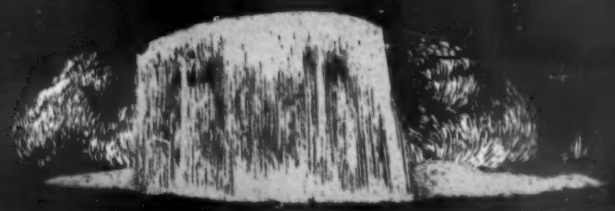

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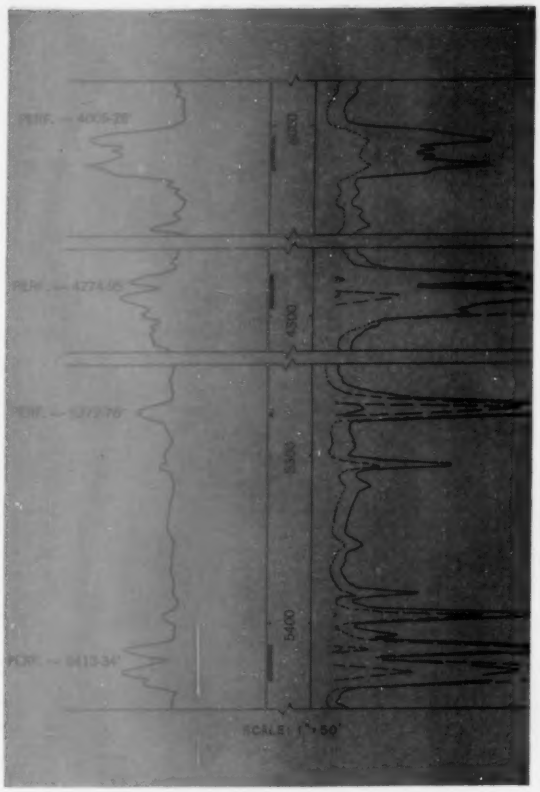


Fig. 2. Sections of electric log of CM&M's No. 1 Methodist Camp show characteristics of productive horizons and perforated interval in each zone.

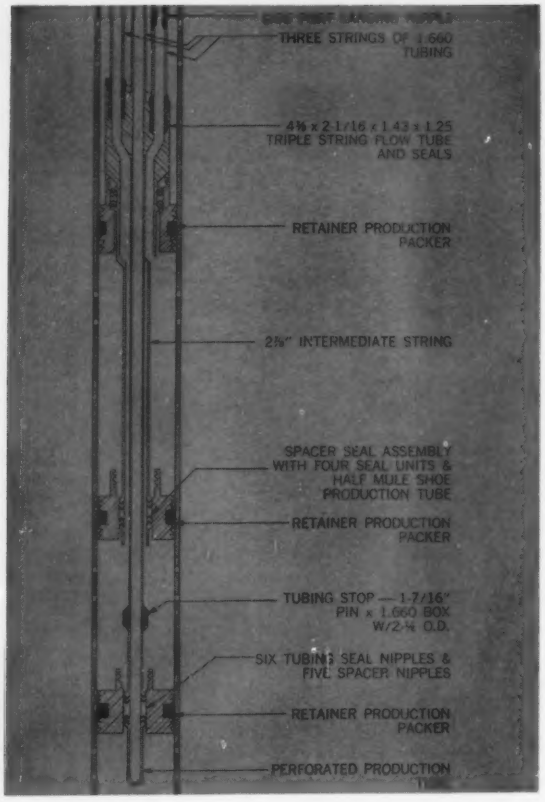

THREE STRINGS OF 1.660 TUBING
4⅝ x 2-1/16 x 1.43 x 1.25 TRIPLE STRING FLOW TUBE AND SEALS
RETAINER PRODUCTION PACKER
2⅞" INTERMEDIATE STRING
SPACER SEAL ASSEMBLY WITH FOUR SEAL UNITS & HALF MULE SHOE PRODUCTION TUBE
RETAINER PRODUCTION PACKER
TUBING STOP — 1-7/16" PIN x 1.660 BOX W/2-¼ O.D.
SIX TUBING SEAL NIPPLES & FIVE SPACER NIPPLES
RETAINER PRODUCTION PACKER
PERFORATED PRODUCTION

Fig. 3. CM&M's unique quadruple completion required careful planning and execution of installation procedures so that all elements fitted in their proper order. Note how production from each zone is separated. Diagram courtesy Baker Oil Tools, Inc.

Mechanics of the Installation

Previous wells in the area and logs from this particular well clearly indicated the nature and depth of each of the four productive zones. When the casing was cemented, the cement plug was pumped to bottom with clear water. This water was displaced with oil and each zone individually tested, treated and prepared for production prior to installing the packers, flow tube and tubing strings.

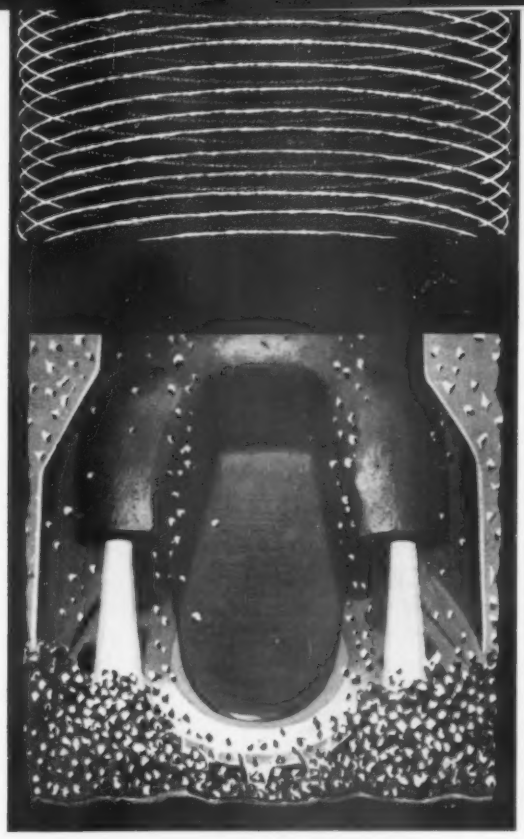
Each packer was set individually by means of electric line at predetermined depths. The flow tube, concentric tubing arrangement and seals were run in on the primary macaroni string (middle string in Fig. 3) and landed as described. As far as the actual running procedure is concerned, seals for the middle packer and outer tubing were first run in the hole and landed in the slips. Safety clamps held the assembly in position. The inner string of macaroni tubing with seals for bottom packer was picked up and run through the outer tubing already in the hole to a point where it was tied into the flow tube.

The manuever was accomplished by blocking up above the rotary table and using an auxiliary bowl and slips to handle the inner tubing string. After both inner and outer strings were run to this point, the flow tube was picked up on the primary macaroni string and attached to the previous two strings. The entire assembly was run in the hole and landed in the top packer. This setting automatically positioned the seals in the top, middle and bottom packers.

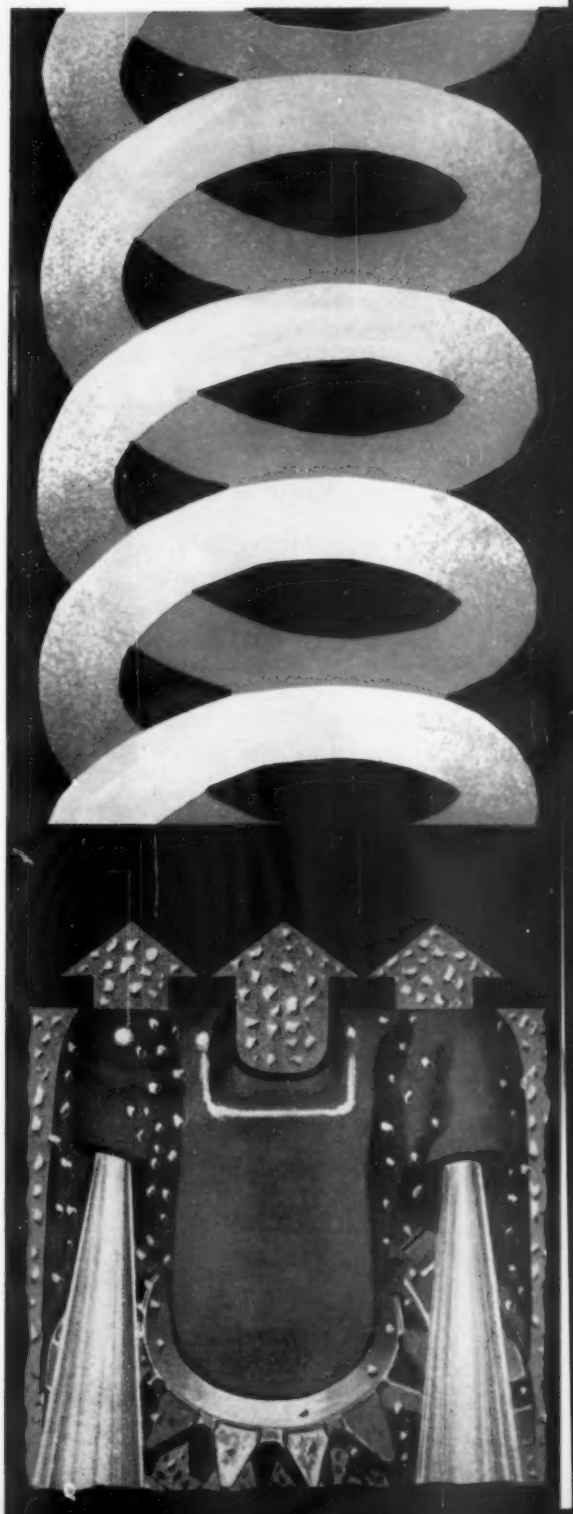
The second and third tubing strings equipped with appropriate seals on bottom were run and seated in the flow tube. Due to the design of the

Table 1. Cost Comparison Between One Quadruple and Two Dual Completions in the Boonsville Bend Field Area.

Cost items	Cost of LT & MT dual	Cost of UT & C dual	Cost of quadruple
Surface casing cemented	$ 750	$ 750	$ 750
Drilling	19,800	13,500	19,800
Logging	885	550	885
Mud	3,590	1,500	3,590
Location	2,400	2,400	2,400
Miscellaneous	1,500	1,000	2,000
Total drilling cost	$29,217	$19,992	$29,717
Producing casing cemented	8,000	5,000	8,000
Misc. completion services	1,200	1,200	3,000
Christmas tree	600	600	2,411
Tubing	4,500	2,700	7,458
Subsurface equipment	300	300	2,000
Total completion cost	$ 9,800	$ 9,800	$22,869



milling or drilling?



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flow tube, it was essential that the second and third strings be run and landed in a counterclockwise direction in reference to the primary tubing string.

After all strings were run and landed, each individual string was swabbed in. A side port nipple in the third string permitted production from the top zone to be brought in with the zone immediately below the top packer (second zone). A separation tool was run later in this side port nipple to separate these two producing zones. Due to the flexibility of the side port nipple, bottom-hole pressure surveys can be made on the reservoir producing into the casing annulus.

Tubing instruments can be run to bottom through the primary (middle string in Fig. 3) tubing string. Flow channel through the flow tube for this string is full open for the size of macaroni tubing used in this well.

Packer leakage tests were made on each zone after all four horizons were brought into production.

The Methodist Youth Camp No. 1 well was completed in February 1961, and all four zones have been producing satisfactorily ever since.

Economics of Completion

The decision to make such a quadruple completion must take economics into consideration as well as operational requirements. The cost of a quadruple completion must be compared with that of the next best (and most satisfactory) method of completion for the operator concerned, and in the same area. In the Boonsville Bend area dual completions function very well. So, to be reasonable and fair, the economic comparison was made with two dual completions rather than with four single-zone completions.

A dual completion in this field normally utilizes 2⅜-in. EUE tubing and 5½-in. OD casing. If Christie, Mitchell & Mitchell Co., were to receive the same allowable and income from dual wells as from one quadruple well, two such dual completions would be required. Therefore the cost evaluation shown in Table 1 was made on this basis. Cost of a dual well in the lower two zones (1-LT, 5400-ft conglomerate and 1-MT, Bend conglomerate) is detailed in the left-hand column of Table 1. The second column shows cost breakdown for a dual completion in the upper two zones (the 1-UT or 4300-ft Strawn and the 1-C or 4000-ft Morris).

An analysis of these figures show the biggest saving brought about by the quadruple completion is in cost of drilling. The cost reduction alone amounts to \$19,492 (\$29,217 + \$19,992 − \$29,717 = \$19,492).

Dollar savings in the completion phase are not as great as are represented in cost reduction for drilling. Considering the completion cost of two duals vs one quadruple, the difference amounts to \$1531 (\$14,600 + \$9800 − \$22,869 = \$1531). Total dollar savings for the quadruple well (both drilling and completion) amount to \$21,023.

Acknowledgment

Early planning of the quadruple completion program and conception of the idea originated with Morris D. Thompson, Jr., production manager for CM&M at Houston. Ernest Frnka, CM&M's district superintendent at Bridgeport, Texas, supervised these installations.

Thanks go to J. C. Burtner, division staff engineer, Baker Oil Tools, Inc., Houston, Texas, for his assistance in designing the quadruple completion and for his contribution to this discussion.

■

About the Author

Gordon E. Taylor is division production engineer at the headquarters office of Christie, Mitchell & Mitchell Co., Houston, Texas, and is a registered professional petroleum-natural gas engineer in the state of Texas. A 1947 graduate from Texas A&I College at Kingsville, Texas, with BS in natural gas engineering, he joined Socony Mobil Oil Company as a natural gas production engineer. After serving with Mobil in Louisiana, Oklahoma and South and West Texas, he entered business for himself in November 1952. In August 1955, he joined Trio Drilling Company and worked principally in North Texas as a drilling and production engineer until February 1957. He became district drilling engineer at this time for Christie, Mitchell & Mitchell Co., in North Texas until his transfer to CM&M's home office as division production engineer in July 1959.

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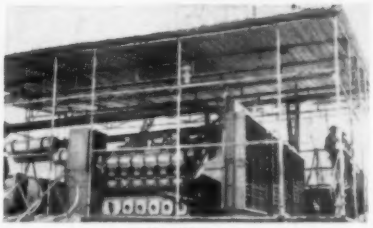

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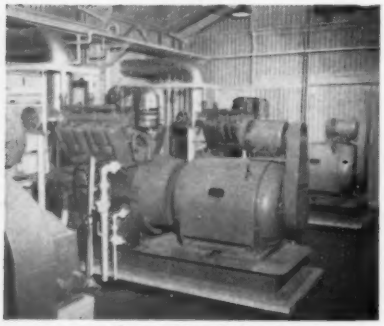

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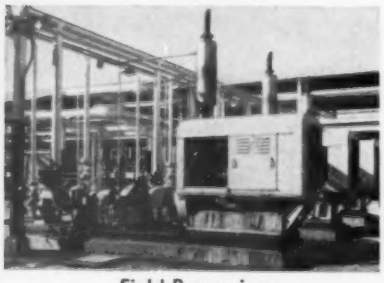

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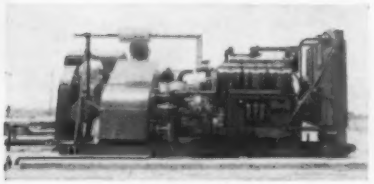

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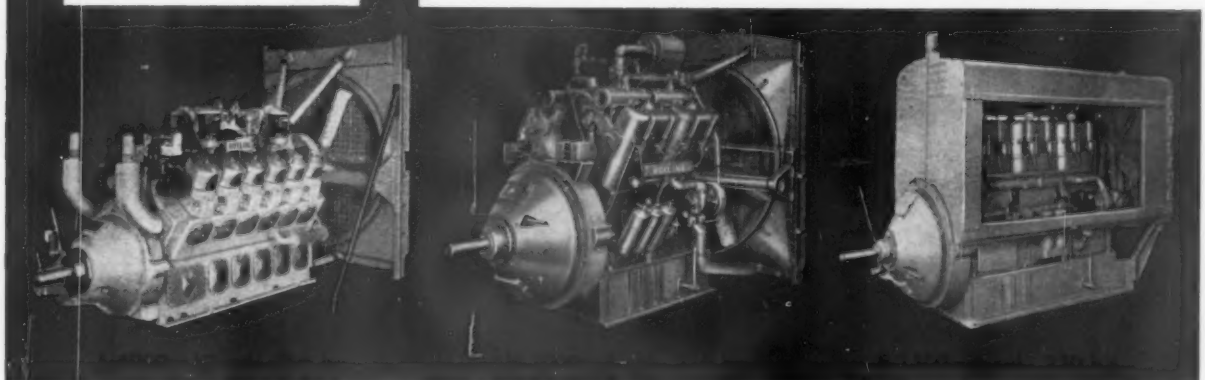

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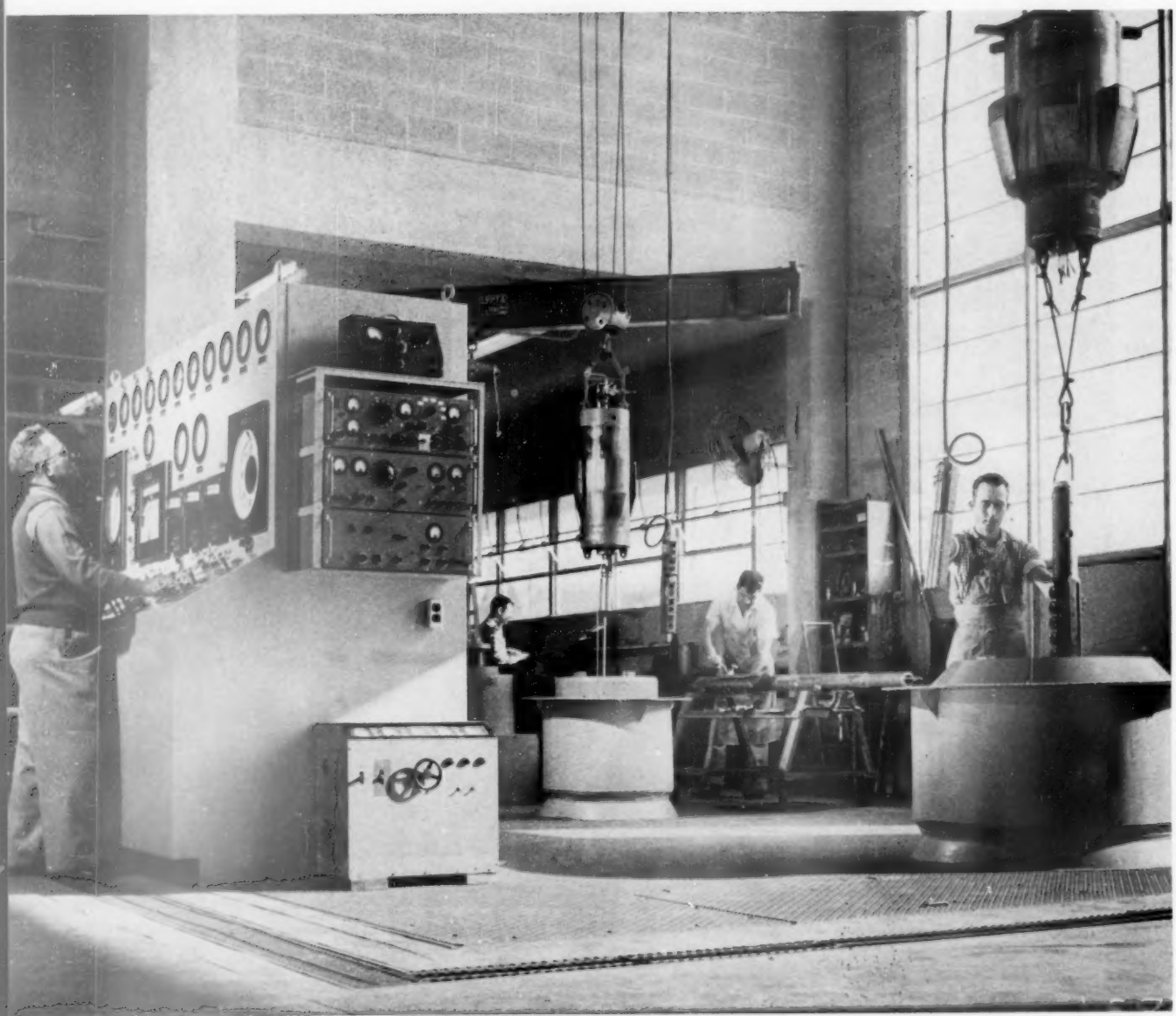


Downhole tools are tested under simulated well conditions in this pressure-temperature installation at Schlumberger's Houston research laboratory. Unit can go to 30,000 psi and 450 F.

Those Hot Holes

Heat and pressure barriers in logging and perforating ultra-deep wells have been broken. Thanks to years of extensive research, you can accurately log those hot holes to 400 F and safely perforate to 430 F.

Downhole tools using new heat-resistant materials are part of Schlumberger Well Surveying Corp.'s continuing research program to produce even newer ways and means to handle heat and pressure problems in deepest drilling.

Critical electronic components are screened by subjecting them to operating checks while immersed in oil at 400 F. Finished assemblies are subjected to heat tests in which temperatures are raised by stages while operating characteristics are checked and recorded.

Even the cable, which supplies power to the instrument and through which signals must be sent to the surface recorder, is not exempt from temperature considerations. Insulating properties of materials decrease as temperature increases. Downhole devices must be designed to reduce this effect to insignificance on the finished log. As a result of such studies, cables that withstand temperatures well above 400 F have been produced.

In completion services, the effect of high temperature on explosives introduces other difficulties. Exhaustive studies have been made in Schlumberger laboratories on relations between temperature, explosive power and operating safety of charges used in bullet and shaped-charge perforators. The result is an explosive package that can be safely used to perforate wells at temperatures up to 430 F.

High hydrostatic pressures are also problems in deep wells. Much engineering work has gone into developing sondes and housings that withstand bottom-hole pressures greater than 20,000 psi.

The pressure problem increases when drilling mud is gas cut. Aided by the high temperature, which increases rubber's permeability to gas, high pressures force gas into the conductors' insulation and rubber coverings of other metal parts. When the device reaches the surface, this occluded gas expands, sometimes bursting the rubber. Therefore, insulating materials must be chosen to be as impervious to gas as possible.

If reliable downhole tools for such stringent conditions are to be produced, they must be tested under simulated conditions at least equal to the pressure and temperature extremes to be encountered in use.

For this purpose Schlumberger operates at its Houston plant four high-pressure, high-temperature vessels. The first such vessel, with a rating of 10,000 psi, was set up in 1942. The latest unit to be installed operates at a maximum pressure of 30,000 psi and 450 F. Pressure-temperature testing equipment of the size and scope of this Schlumberger device is found nowhere else in American industry.

If historical trends continue, well depths will reach 35,000 ft by 1975. Mud pressures will measure 30,000 psi or more and bottom-hole temperatures may reach 600 F.

Deep in South Texas on what is known as the Pescadito Dome, several wells have already tested the mettle of logging and perforating tools. Early in 1960 in this area Hunt Oil Co. of Dallas encountered bottom-hole temperatures which measured 456 F at 20,603 ft. Because the bottom of this wildcat was so hot, it was decided not to case the hole in order that formation testing could be achieved without setting pipe and risking a touchy perforating problem at such elevated temperatures.

And, it appears that high temperatures and pressures will be with operators who will continue at a more rapid pace than ever to drill wells below 20,000 ft. ■

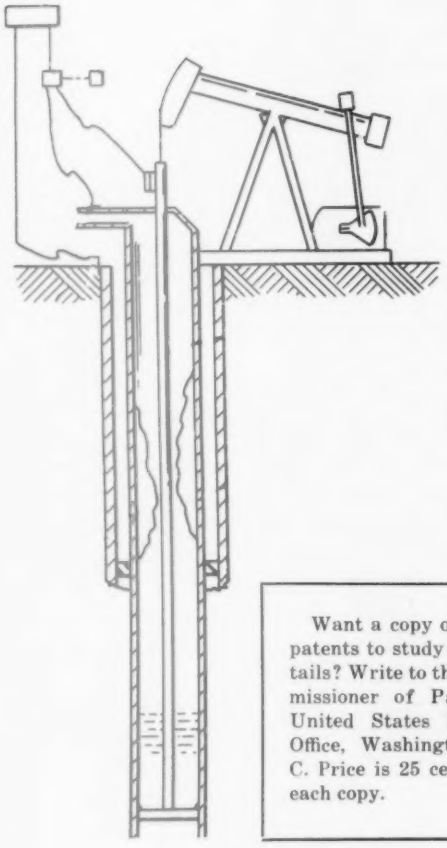
Brief notes on selected oil field patents recently granted

What's New in Patents

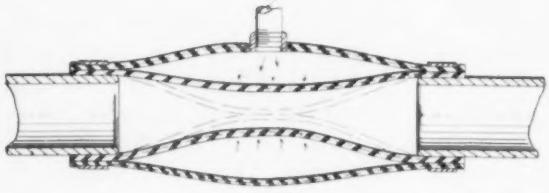
by Paul H. Johnson, James R. Head

Electric Current Removes Accumulated Paraffin

The application of sufficient electric current to heat the tubing string and melt accumulated paraffin is described in this patent. The invention particularly relates to use of strain gages affixed to the polished rod to actuate the heating current. When paraffin accumulates to the point of increasing the load on the rod string, the strain gage activates the electrical circuit to heat the tubing and remove the paraffin. Patent No. 2,982,354, Paraffin Removing Device, W. G. Green.



Want a copy of these patents to study the details? Write to the Commissioner of Patents, United States Patent Office, Washington, D. C. Price is 25 cents for each copy.

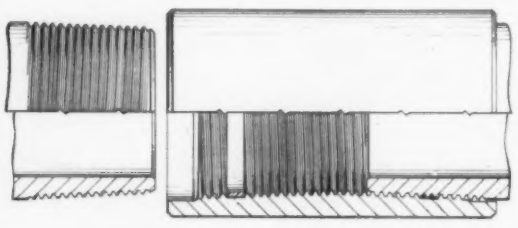


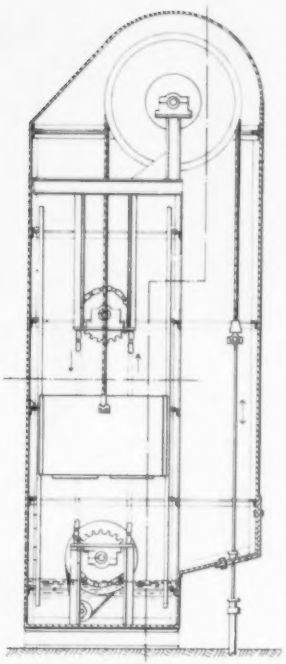
Hydraulic Pressure Operates Resilient Control Valve

Fluid or gas pressure is used to operate the control valve described in this patent. A double concentric flexible sleeve is used to join the two pieces of pipe. Hydraulic pressure applied outside the inner sleeve causes the sleeve to restrict the flow area and reduce the flow of fluid. When pressure is reduced, the sleeve returns to its normal configuration and offers substantially no resistance to flow. Design of the valve is such that no mechanical components need be contacted by the fluid flow. Patent No. 2,982,511, Pressure-Operated Control Valve, D. M. Connor.

Pipe Coupling Features Built-In Sealing Ring

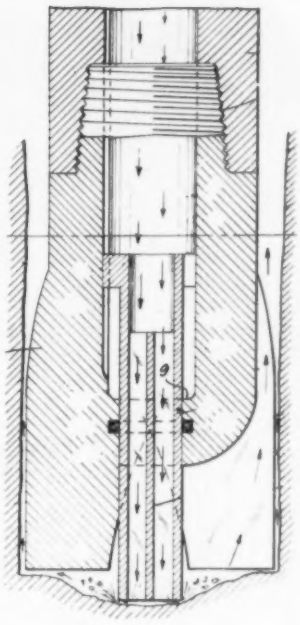
For high-pressure service, this pipe coupling has a resilient sealing ring placed in the threads. When the connection is made up, threads on the pin end of the pipe engage and protrude into the packing and form an extra seal to contain high pressures. Patent No. 2,980,451, Threaded Pipe Joint Having an Extrudable, Generally Non-Resilient Sealing Means, W. B. Taylor and W. H. Griffin.





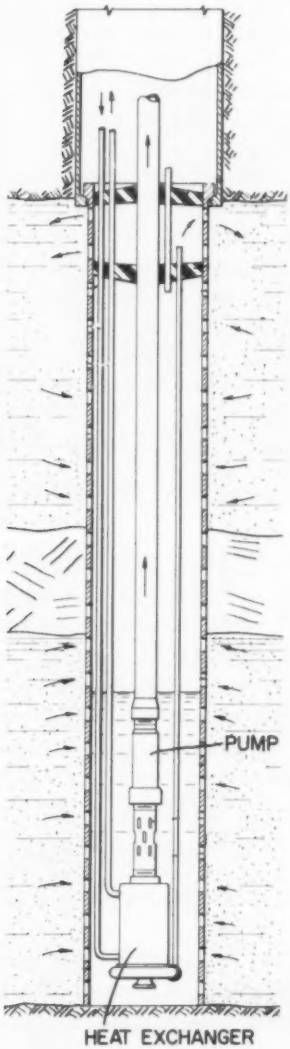
Pumping Unit Has Chain-Driven Counterbalance

A completely enclosed pumping unit with a chain-driven counterbalance weight is described in this new patent. The counterbalance is attached to an endless chain through a mechanism which permits the weight to travel up and down as the chain turns continuously. A cable extends from the weight over a pulley to the polished rod. Patent No. 2,977,808, Pump Jack, R. H. Dobbs.



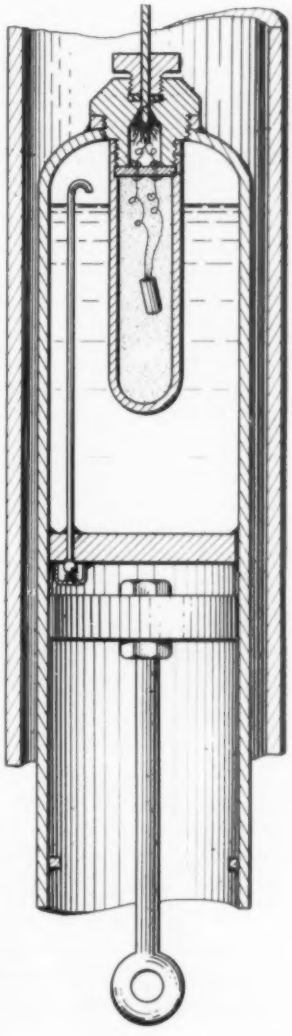
Hydraulic Drill Bit Uses Large Mud Jet

Benefits of the hydraulic drilling force of drilling mud jets are incorporated in the bit described in this new patent. The bit is equipped with an extendable tube which protrudes from the center of the bit and conducts high-pressure mud to the face of the rock being drilled. The tube is forced against the face of the rock by hydraulic pressure at the upper end of the tube. The high-pressure jet keeps the drilled face swept clean of cuttings and, in softer formations, actually washes away the formation. Patent No. 2,963,102, Hydraulic Drill Bit, J. E. Smith.



Downhole Heat Exchanger Increases Formation Temperature

Heavy, viscous oil presents production problems which can often be lessened by the application of heat downhole to reduce viscosity of the oil. Various methods have been devised to heat the tubing and fluid in the well bore. This patent, however, covers a method designed to raise the temperature of the surrounding formation by placing a heat exchanger down the hole opposite the producing formation. Heated fluid is pumped through small tubing from the surface and then circulated back to the surface. Size of the heat exchanger, as well as type of fluid used, depends upon heat requirements. Patent No. 2,980,184, Method and Apparatus for Producing Wells, D. W. Reed.



One-Stroke Engine Unit Powers Downhole Tools

In situations where one powerful stroke is needed downhole, such as setting certain packers or displacing a batch of treating fluid, this tool may prove beneficial. A chamber containing a vaporizable liquid is connected through a small tube to a cylinder above the working piston. A sealed container of exothermic reaction materials, such as powdered aluminum and powdered ferric oxide, is provided with an igniting device which is triggered from the surface. The resulting exothermic reaction generates heat which vaporizes the fluid into gas which in turn expands to force the piston downward. Patent No. 2,965,078, Piston Engine Unit for Submerged Operation in Wells, J. D. Chestnut and J. M. Carter.

by L. T. Stanley

Curve-Fitting Cuts Material Balance Calculations

With a new curve-fitting procedure you can quickly approximate reserves of water drive reservoirs by material balance.

This method will provide an estimate of the most probable values of oil in place and water influx while eliminating many of the trial-and-error computations of other methods. Reserves can be estimated rapidly with a desk calculator.

When applied to four gas reservoirs and one oil reservoir, the procedure produced results comparable in accuracy to those obtained by two complex methods.

The new method employs the superposition theorem but introduces some simplifying ideas concerning the dimensionless water influx function Q_T. The standard deviation on a single variable is used for determining the probable values of the desired constants.

Water Influx

Cumulative water influx across the boundary of a reservoir expressed as a fraction of the pore volume may be represented by

$$\int_0^t q_t dt = 2\pi\phi c R_b^2 \Delta p G(T) \quad . \quad . \quad . \quad (1)$$

where $G(T) = \int_0^T F(T)\,dT$.

A plot of F(T) vs T would show the decline in influx rate as a function of dimensionless time T for a fixed value of Δp, the decline being a consequence of the continuous recession of the drainage radius as it moves outward from the field boundary. Consequently, a plot of G(T) vs T would show the cumulative influx with time for a fixed value of Δp.

As the influx rate decreases, G(T) increases, but at a decreasing rate, until it finally approaches a linear increase with time. This is true regardless of the properties of reservoir and aquifer.

Therefore, the shape of the G(T) curve is predictable in advance of any computations. It is a curve whose slope decreases monotonically; i.e., as the curve is followed in the direction of increasing time, its slope either decreases or is constant, but never increases. The slope has its greatest value at $T = 0$.

It can be generalized then that $G(T) = (\sum_0^t \Delta \bar{t})^n$ where $\Delta \bar{t}$ is a unit increment of dimensionless time and $1 > n > 0$.

Hutchinson and Sikora[16] have used the characteristic shape of the influx function to develop a water drive analysis by which historical influx and pressure data are fitted by trial-and-error to arbitrary "resistance" or "Z-functions." Their concept has much in common with the new method, but it requires that the oil in place be known.

Fig. 1 shows a group of curves of the monotonic type. The Van Everdingen-Hurst curves are plots of $\int_0^T \left(\frac{\partial p}{\partial r}\right)_{r=1} dt$ vs dimensionless time as derived by application of the Laplace transformation to the diffusivity equation. Influx functions for radial and linear cases are ap-

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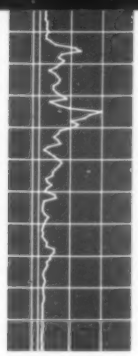

Two men...the inspiration for six thousand

OIL INDUSTRY PROGRESS HAS BEEN MARKED BY MEN WITH THE COURAGE TO RISK FAILURE . . . AND THE KNOWLEDGE, IMAGINATION, AND STAMINA TO ATTAIN SUCCESS. ■ SCHLUMBERGER PROGRESS HAS BEEN SIMILARLY ACHIEVED. ■ CONRAD AND MARCEL SCHLUMBERGER TOOK THE IDEA OF SUBSURFACE ELECTRICAL MEASUREMENTS AND, WITH KNOWLEDGE, IMAGINATION, DARING, AND PERSEVERANCE, DEVELOPED ONE OF THE MOST VALUABLE CONTRIBUTIONS TO THE EXPLORATION AND PRODUCTION OF OIL — — ELECTRICAL LOGGING. ■ THEY HAD ANOTHER TALENT . . THE ABILITY TO TEACH, TRAIN, AND INSPIRE THEIR CO-WORKERS WITH THE SAME ZEST FOR EXCELLENCE . . . THE TIRELESS SPIRIT OF SERVICE. ■ MORE THAN 6000 SCHLUMBERGER EMPLOYEES THROUGHOUT THE WORLD ARE GUIDED BY A HERITAGE OF LEADERSHIP AS THEY PERFORM THEIR JOBS OF CONTINUALLY IMPROVING AND EXPANDING THEIR SERVICES TO THE OIL INDUSTRY.

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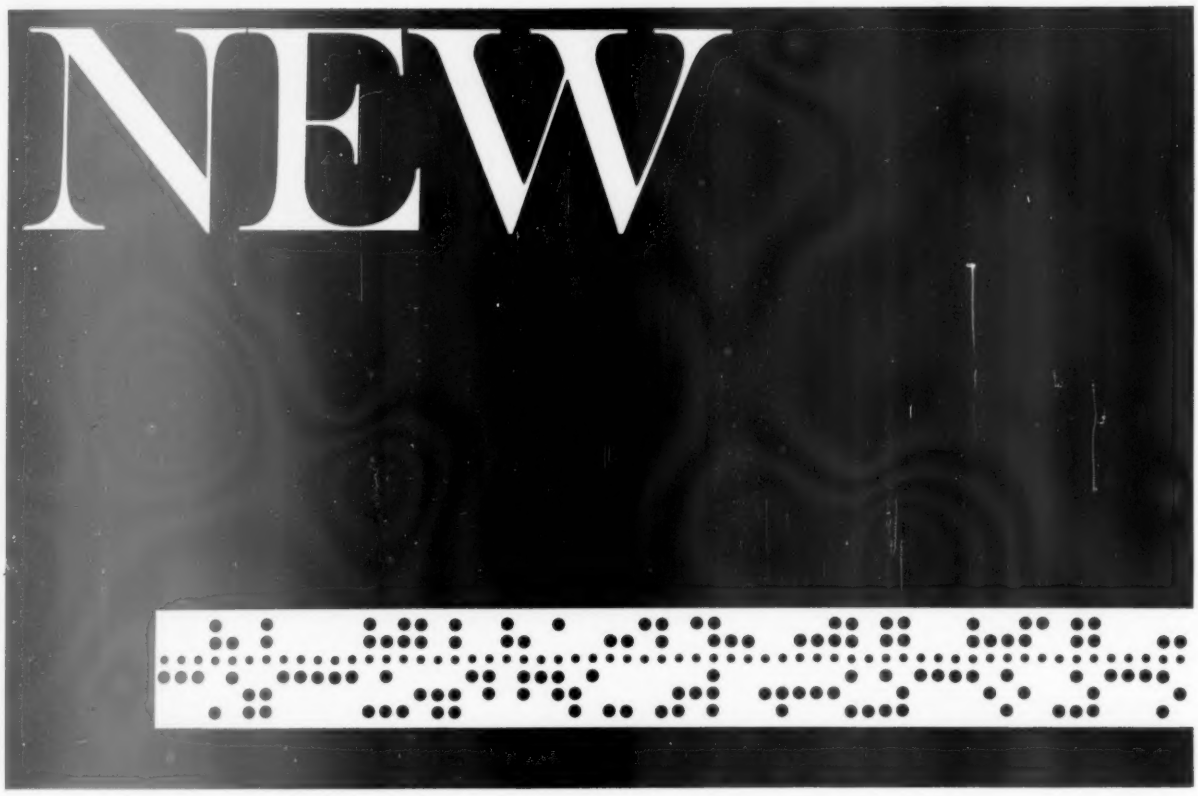

Dowell provides electronic computer calculations to help operators select best frac treatments

Dowell's new electronic computing service is now providing rapid calculations – based on the Frac Guide* – to help operators select fracturing treatments best suited to their needs and available funds. This new service by Dowell costs you nothing extra, yet it offers operators new opportunities for greater profits from fracturing.

The computer provides calculations comparing the effects of different fracturing fluids, injection rates and propping agents for a given set of well conditions.

The computer output shows predicted production increase, treatment cost and payout for each treatment analyzed. These data can be plotted on graphs to give the operator a visual comparison of the treatments being considered.

The big advantage of Dowell's computing service lies in speed of calculations. Until now, it took an engineer something like a full day to calculate a single treatment with only a few variables. The computer requires less than ten minutes. This, coupled with Dowell's nation-wide teletype system, makes it possible to provide customers with many calculations quickly – usually in only a few hours.

Accuracy is another advantage. The computer minimizes the possibility of error in calculations and frees engineers to double check input data for accuracy and completeness. The result is more accurate, more reliable calculations than ever before.

Again, Dowell is helping operators improve fracturing results. Again, there is no extra cost. Ask for full information. Dowell services and products are offered in North and South America, Europe and North Africa. Dowell, Tulsa 1, Oklahoma.

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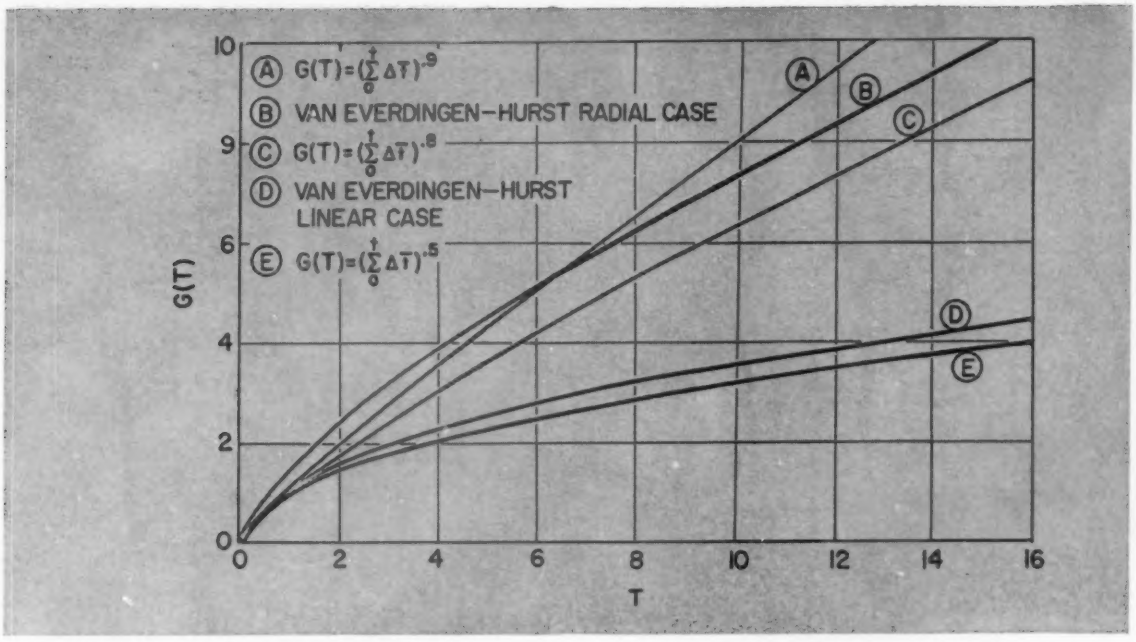

Fig. 1. Water influx integral represented by these typical curves.

proximated by $G(T) = (\bar{t})^{0.8}$ and $(\bar{t})^{0.5}$, respectively; therefore, the influx function of most reservoirs may be expected to fall within the limits $(\bar{t})^{0.8} \geqq G(T) \geqq (\bar{t})^{0.5}$ where $\bar{t} = Ct$ and C is constant for a given reservoir.

Note also from Fig. 1 that the slope $dG(T)/dT$ is approximately the same for the Van Everdingen-Hurst radial and linear cases and for $(\bar{t})^{0.8}$ and $(\bar{t})^{0.5}$, respectively, at $\bar{t} > 2$. This similarity implies that most of the transient history of a reservoir may be described by a simple exponential of time and that arbitrary units $\Delta\bar{t}$ may be selected, permitting a value of C to be determined empirically for any reservoir. On this basis, the water influx becomes:

$$W_e = C \sum_0^t \Delta p(\bar{t})^n{}_{t-t'} \quad . \quad . \quad . \quad . \quad (2)$$

where $0.5 \leqslant n \leqslant 0.8$.

When the unsteady state water influx expression is equated to material balance water influx and terms are rearranged, the following equations result for various types of reservoirs:

For undersaturated oil reservoir,

$$\frac{N_p B_o + W_p}{B_o - B_{oi}} = C\left[\frac{\sum_0^t \Delta p(\bar{t})^n{}_{t-t'}}{B_o - B_{oi}}\right] \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For saturated oil reservoir without gas cap,

$$\frac{N_p B_t + N_p (R_p - R_{si})\, B_g + W_p}{B_t - B_{ti}} = C\left[\frac{\sum_0^t \Delta p(\bar{t})^n{}_{t-t'}}{B_t - B_{ti}}\right] + N \quad . \quad . \quad . \quad (4)$$

For saturated oil reservoir with gas cap,

$$\frac{N_p B_t + N_p (R_p - R_{si})\, B_g + W_p}{B_t - B_{ti} + mB_{ti}(B_g/B_{gi} - 1)} = C\left[\frac{\sum_0^t \Delta p(\bar{t})^n{}_{t-t'}}{B_t - B_{ti} + mB_{ti}(B_g/B_{gi} - 1)}\right] + N. \quad (5)$$

For gas reservoir,

$$\frac{G_p B_g + W_p}{(B_g/B_{gi} - 1)} = C\left[\frac{\sum_0^t \Delta p(\bar{t})^n{}_{t-t'}}{B_g/B_{gi} - 1}\right] + G. \quad (6)$$

It is apparent that each of these equations is linear, first order, and the constants are C and N or G. It also is apparent that the two variable terms in each equation are determined by pressure and production history. Therefore, for any reservoir, if the exponent n is known, the values of C and N or G which best satisfy the linearity of the equation are the most probable values.

Graphical procedures can be employed to determine an order of magnitude estimate. For more precise requirements, a simple statistical procedure will provide an unbiased estimate of the constants.

Estimating Procedure

The procedure is to fix a value of n and select the value of N or G which results in minimum variation of C. That is, the combination which gives the least deviation of C_m (the arithmetic average of all C's in a set) is considered repre-

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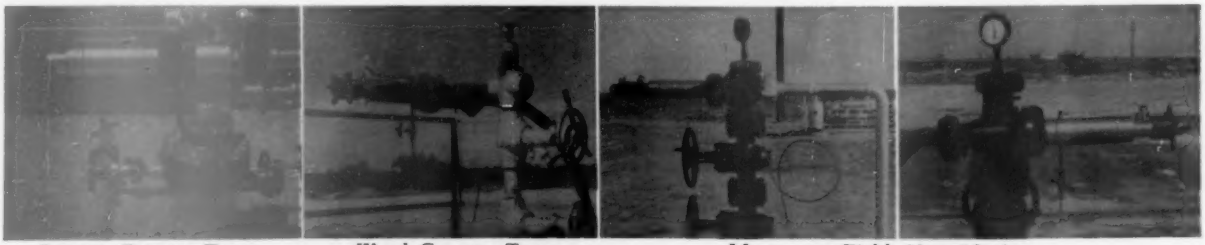

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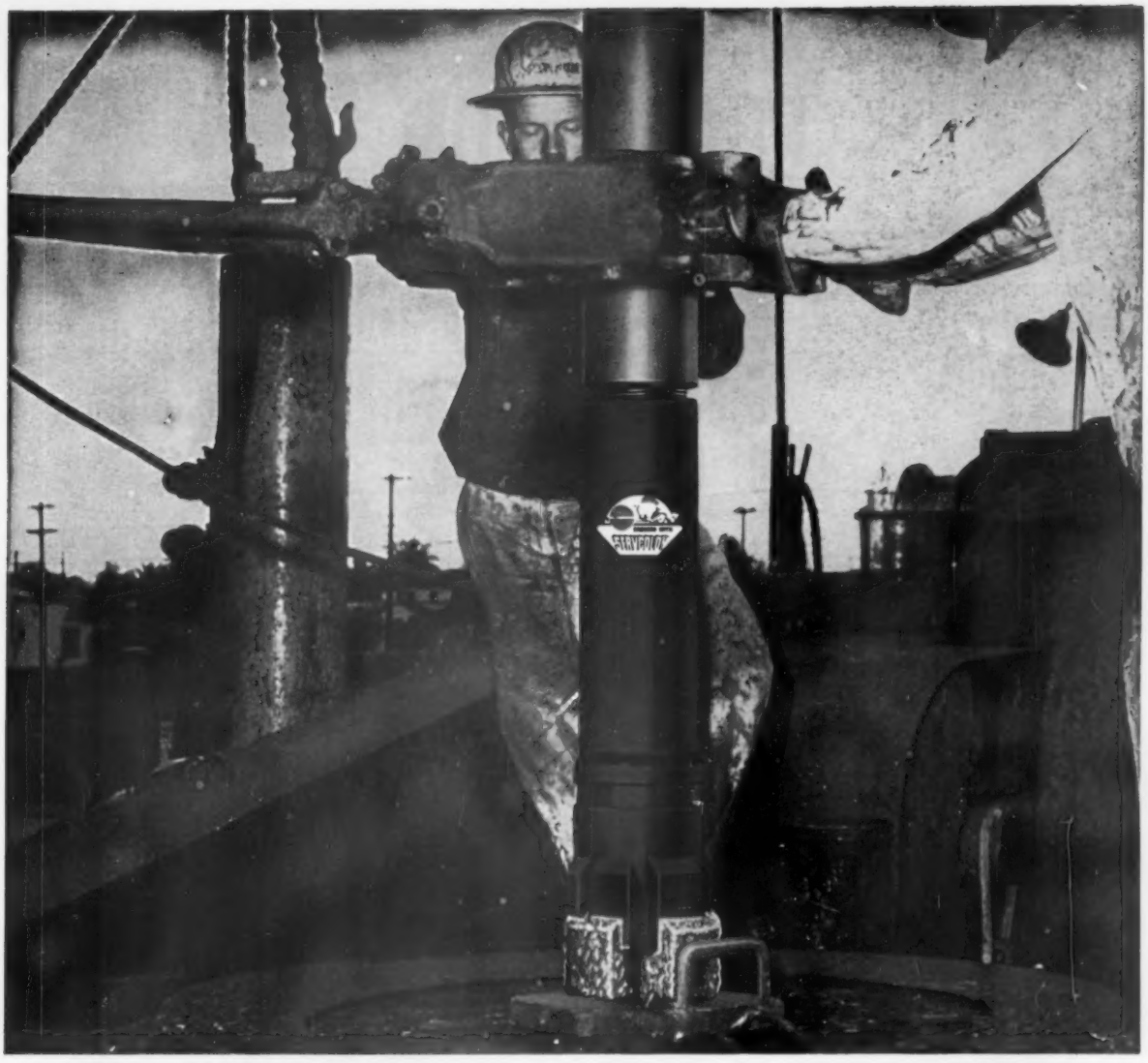

Three 6⅛" Bit Cones milled up in 2 HOURS!

Servcoloy-dressed Junk Mills chew up bit cones and other junk with amazing speed; makes this method of removing a fish fast, safe, and very economical.

After three cones from a 6⅛" bit were left on bottom, two rock bits, two hydro-bailers, and two junk baskets were run during a three-day period in attempts to either recover or sidetrack the three cones. Results were negative.

A six-inch Servco CJ Junk Mill dressed with Servcoloy, was then run in the hole. A total of two feet of hole was drilled in a period of two hours of milling. The operator ran back with a bit and proceeded to drill a head. Fine steel cuttings were caught on the shaker during the milling and appeared on the mud screen during the succeeding day, showing that the *cones were actually milled up, not sidetracked.*

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Servcoloy is a patented, hard-facing material which uses a unique method of suspending bits of carbide in a tough, elastic matrix. As the carbide cutting edges are worn away or torn from the matrix, new edges are automatically exposed. Servcoloy is now being used on Servco milling tools such as section mills, rotary shoes, taper mills, pilot mills, etc. Remedial work which formerly took days to do is now being done in hours.

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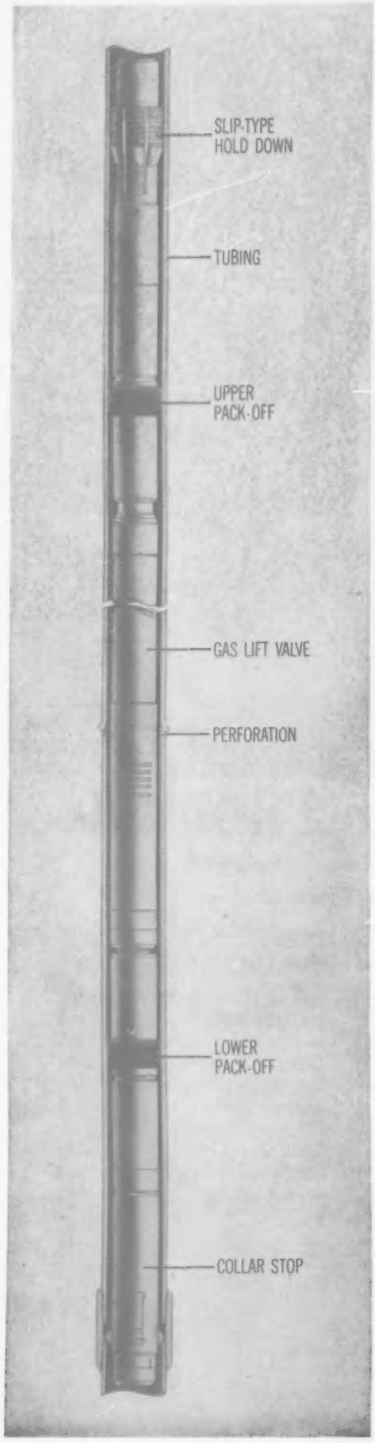
*U.S. Patent No. 2,833,638

OTIS PRODUCTION NEWS

Volume II, Number 3 **Otis Engineering Corporation • Dallas** *Production Equipment and Services*



Cost-Conscious Producing Companies Endorse Otis All Wire Line Technique Of Converting Wells to Gas Lift

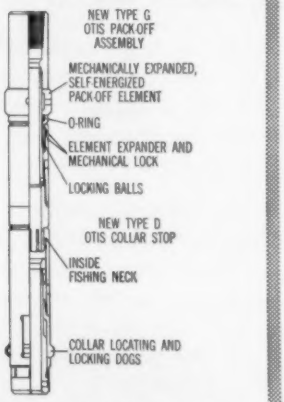
CORPUS CHRISTI—Eliminate the cost of a pulling unit to round-trip tubing when converting a well to gas lift and you can save an impressive amount of money per well. That's what several of the major producing companies in this area discovered when they started using the new Otis "All-Wire-Line" Gas Lift Conversion Technique.

A spokesman for one of these majors recently stated that his company is most enthusiastic about the technique — especially for water locations — because "(1) it's faster, (2) it's less expensive, (3) it's every bit as efficient as other types of installations they have made, and (4) it eliminates the risk of damage to the producing formation from contamination by mud and/or water in the annulus." Another company reported a savings of $60,000 in converting three, readily accessible, land locations.

As an example of how the technique can reduce the cost of a conversion, take a look at the following case history: A 6800-foot well located in approximately three feet of water in the Copano Bay Field ceased to flow naturally and was scheduled to be put on gas lift. In making plans to have the work done, it was discovered the approach canal had filled with silt and sand, which meant an expensive dredging operation would be necessary before a barge-mounted workover unit could be moved onto location; cost of a workover unit would be $1400 per day, and the annulus was loaded with old drilling fluid. Estimated conversion costs were mounting fast. A conference with the Otis Gas Lift Specialist in the area convinced the operator he should try a Type CG Otis Pack-Off Gas Lift Valve installation.

After setting a circulating plug in the tubing at the spot indicated for the lower-most valve, perforating and circulating mud from the annulus, it took the trained Otis Wire Line Specialist only 15½ hours of wire line time to perforate and install five concentric Type C Gas Lift Valves between Type G Otis Pack-Off Assemblies and have the well ready to be put back on production. Eight months following the conversion, the well was still making its allowable in an economical and efficient manner. And to attest to the reliability of the new Type G Otis Pack-Off Assemblies, the well was being produced from the lower-most valve.

Otis Gas Lift and Completion Specialists are interested in helping you find a way to complete and produce your wells in the most efficient manner. The experience these men have accrued throughout the years is yours to draw from when faced with any down well completion or production flow control problem. Use the knowledge these men have to offer and you will find you'll be spending your production dollars more efficiently. For more information on the Type CG Otis Pack-Off Gas Lift Valve, call the Otis office nearest you or write Otis, Dept. 3-W, Box 35206, Dallas 35, Texas. You'll find your Otis specialists ready to help you — anxious to serve you.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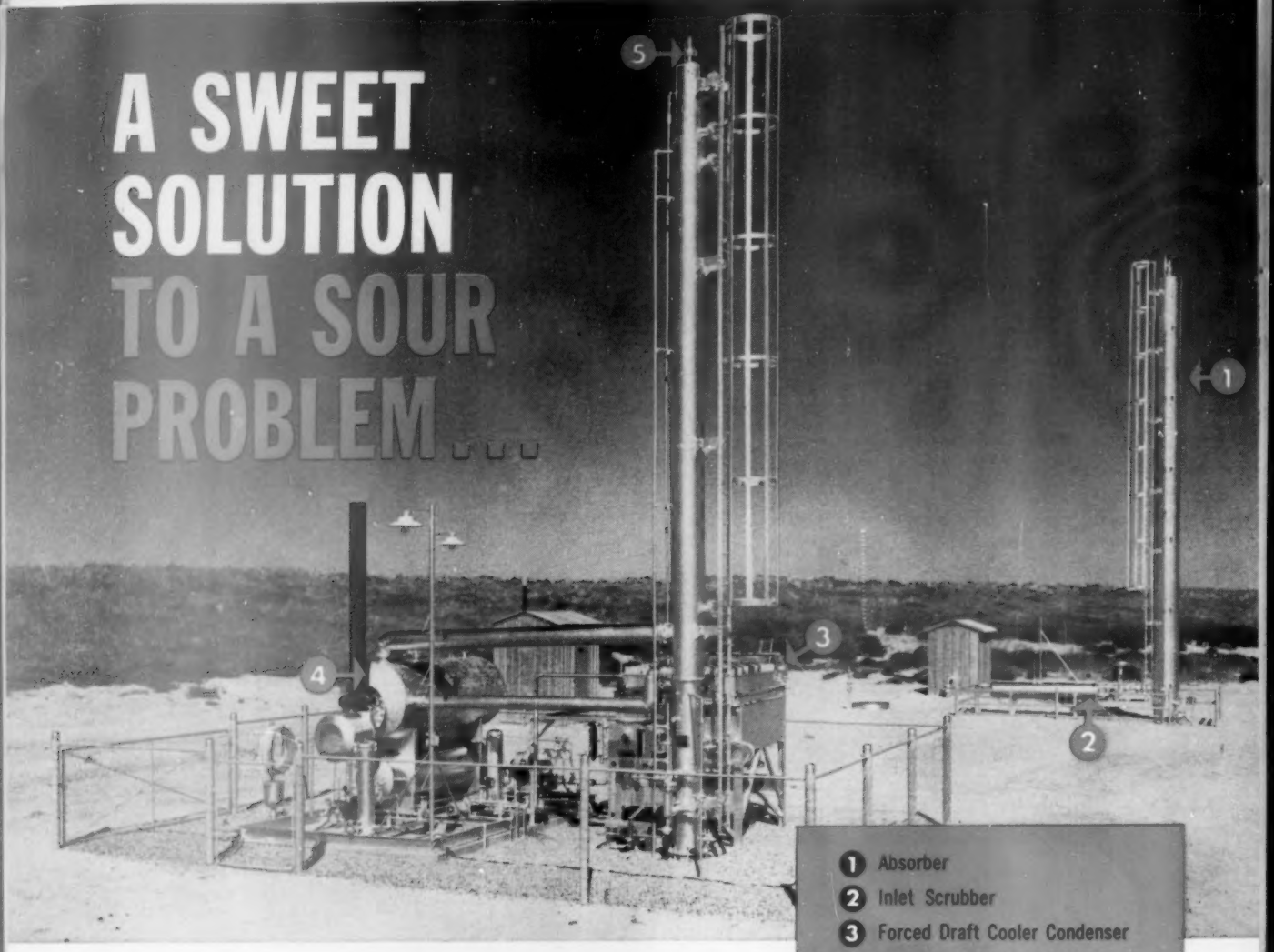

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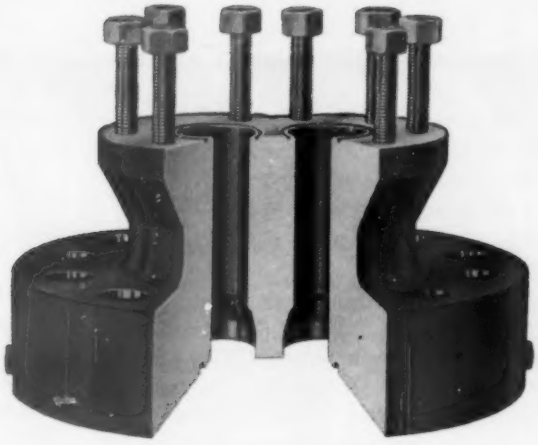

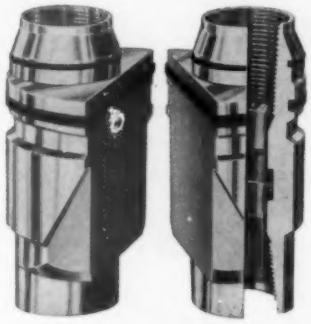

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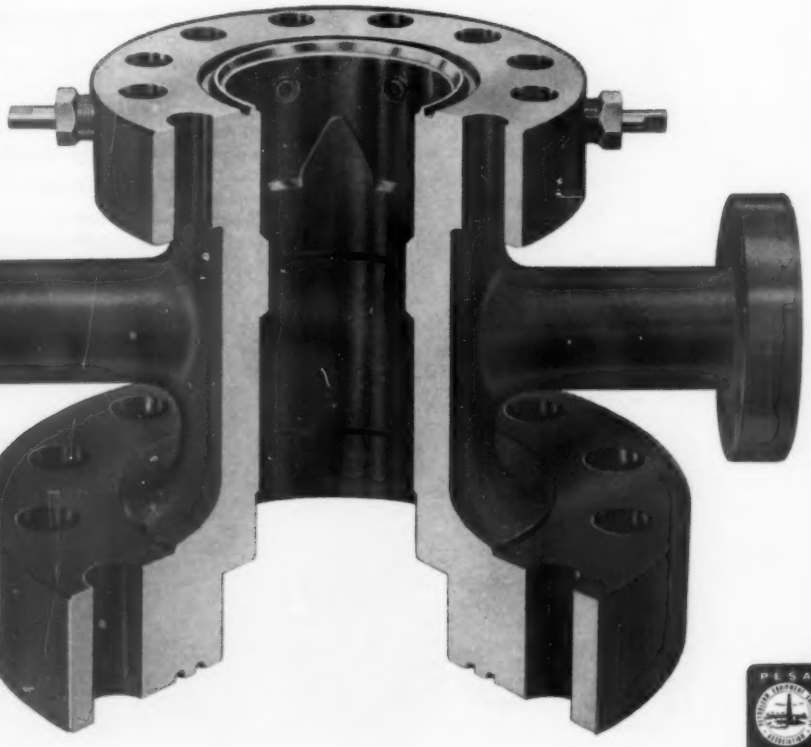

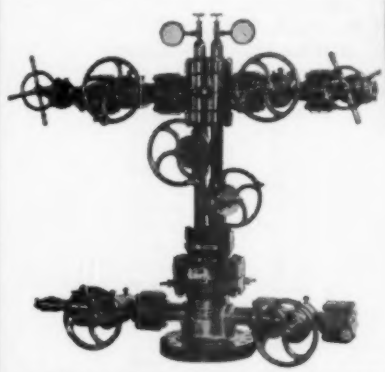

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sentative of the most probable values, $\bar{C}$ and $\bar{N}$ or $\bar{G}$.

The exponent n may fall between the limits of 0.5 and 0.8, but in practice it has been found that one of the limits will satisfy the accuracy required of a reserve estimate, so it is sufficient to test $(\bar{t})^{0.5}$ and $(\bar{t})^{0.8}$ and select the one which fits the data better.

Note that Eq. 3 through 6 are simplified forms of the material balance in that they do not contain terms for rock expansibility, connate water expansibility or the time-wise decrease in reservoir volume due to water encroachment. The computational method need not be restricted to the simplified forms, because the more complex equations still can be expressed in the required linear manner.

To determine C and N or G:

1. Divide the reservoir pressure and production history into a convenient number of equal time increments and assign each time increment a value unity so that $\bar{t}_1 = 1$, $\bar{t}_2 = 2$, etc. Compute the average pressure drop during each time increment.

2. Calculate $\sum_{i=1}^{n_1} (\Delta \bar{p}_i)\ (\bar{t})^{0.8}{}_{n_1} + 1 - i$ and

$$\sum_{i=1}^{n_1} (\Delta \bar{p}_i)\ (\bar{t})^{0.5}{}_{n_1} + 1 - i.$$

Table 1. Comparison of Reserves Computed by Different Methods.

Type of reservoir	Porosity-thickness method	Van Everdingen, et al method	Simplified method
Gas	150	NA*	58
Gas	16	NA*	17
Gas	1055	689	670
Gas	67	63	65
Oil with Gas Cap	2928 oil 452 gas	2553 oil 396 gas	2761 oil 427 gas

*Not available

3. Select several values of N or G that will bracket the anticipated value and compute C for each value of N or G at selected time points throughout production history by using Eq. 3, 4, 5 or 6. (Often it will be found that values of C calculated for early history of a field will not conform reasonably to the remainder of the data. This may be because the influx functions do not truly represent the aquifer performance during early history; or because the early pressure and production history do not represent the aquifer boundary condition, or because of combinations of these. In such cases it has been found advantageous to omit this early history from the analysis.)

4. Make a plot of C vs time with N or G as a parameter for the cases $n = 0.5$ and $n = 0.8$.

5. Inspect the plots for evidence of convergence. If the assumed values of N or G bracket the true value, a reversal of inflection (from concave upward to concave downward) will occur somewhere between the lowest and highest values selected for N or G. The value of n which produces the least variance of C with time is the proper value. For rough estimates, if the field data are accurate and not ambiguous, it may not be necessary to go beyond this step. For more precise estimates, or in cases where there is much scatter in the data, it will be necessary to go to the next step.

6. Compute the standard deviation of Cm for each case selected, and plot standard deviation vs N or G. The value of N or G that produces the minimum deviation is the proper one. The standard deviation is:

$$\sigma = \left[\frac{\Sigma\ (C_m - C_1)^2}{n_1 - 1}\right]^{1/2} \quad . \quad . \quad . \quad . \quad (7)$$

The foregoing discussion is based on the assumption that the aquifer is unlimited; how-

Table 2. Calculation of C at $G \times B_{gi} = 700 \times 10^6$ and $n = .8$ for a Gas Reservoir.

(1) Total prod. time (years)	(2) Avg. Res. press. (psia)	(3) Gas vol factor, B_g (Res. bbl/scf)	(4) Cum. gas prod., G_p (MMscf)	(5) Total withdrawals $G_p B_g$ (MM res. bbl)	(6) $\Delta\bar{p}$ (psi)	(7) $\bar{t}$	(8) $(\bar{t})^{.8}$	(9) $\Sigma(\Delta\bar{p}_i)(\bar{t})_{n_1}{}^{.8} + 1 - i$ (psi)	(10) Total expansion $G B_{gi}(B_g/B_{gi} - 1)$ (MM Res. bbl)	(11) C= (5)-(10)÷(9)
0	3745	0.000826	0	0	0	0	0	0	0	—
0.5	3731	0.000827	2,680	2.222	7.0	1	1	7.0	1.40	0.1170
1.0	3708	0.000834	7,254	6.046	18.5	2	1.74	30.7	5.48	0.0185
1.5	3688	0.000837	12,342	10.330	21.5	3	2.41	70.6	8.47	0.0263
2.0	3670	0.000840	17,497	14.700	19.0	4	3.04	122.3	11.16	0.0289
2.5	3645	0.000844	23,162	19.564	21.5	5	3.62	188.0	14.99	0.0243
3.0	3621	0.000850	30,898	26.238	24.5	6	4.19	269.4	18.84	0.0275
3.5	3595	0.000854	39,909	34.082	25.0	7	4.75	365.8	22.96	0.0304
4.0	3555	0.000862	49,474	42.634	33.0	8	5.27	484.5	29.23	0.0276
4.5	3508	0.000871	60,471	52.674	43.5	9	5.80	633.3	37.17	0.0245
5.0	3470	0.000879	74,126	65.151	42.5	10	6.30	807.4	43.85	0.0264
5.5	3430	0.000888	88,523	78.552	39.0	11	6.82	1002.5	55.15	0.0233
6.0	3383	0.000897	103,237	92.674	43.5	12	7.32	1223.0	59.77	0.0269
6.5	3324	0.000912	117,024	106.640	53.0	13	7.78	1476.4	71.04	0.0241
7.0	3265	0.000925	135,775	125.622	59.0	14	8.25	1765.4	82.92	0.0242
7.5	3220	0.000937	154,123	144.329	52.0	15	8.75	2077.5	92.63	0.0249
8.0	3175	0.000947	172,591	163.565	45.0	16	9.20	2415.6	102.06	0.0255

Will your drilling string return a profit?

When you invest $40,000, $60,000 or $75,000 for a drilling string, you want to be sure that it will return a profit through long, dependable, trouble-free service.

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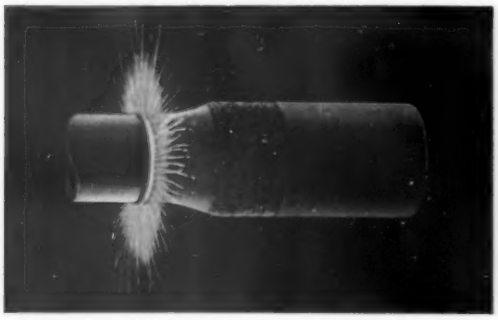

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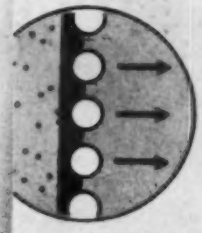
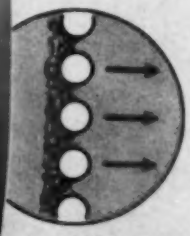
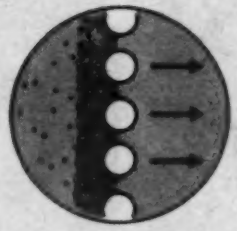


WITHOUT CELITE, fine suspended solids form a clogging seal over filter openings.



WITH CELITE, a porous cake with microscopic channels becomes the real filter surface.



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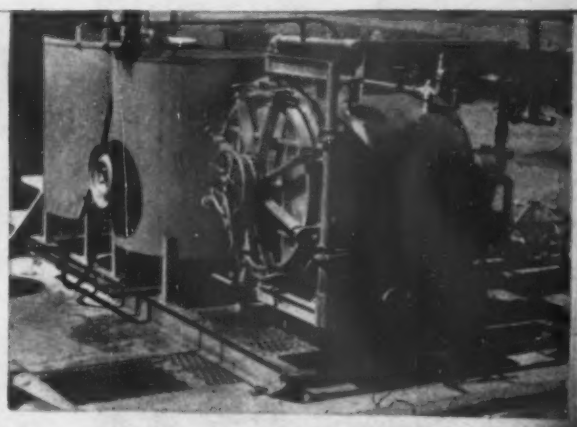

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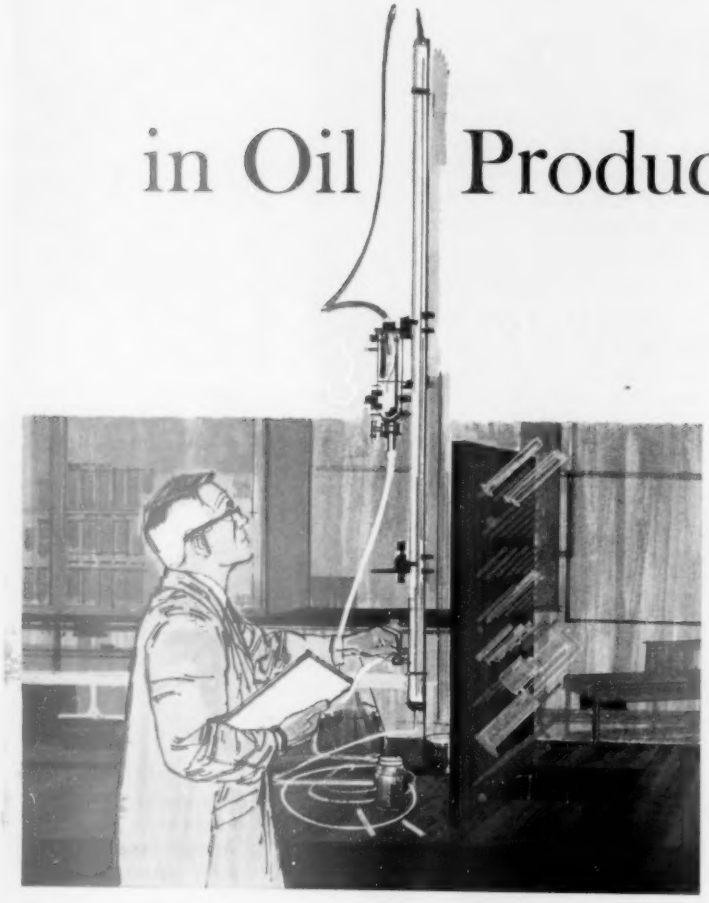

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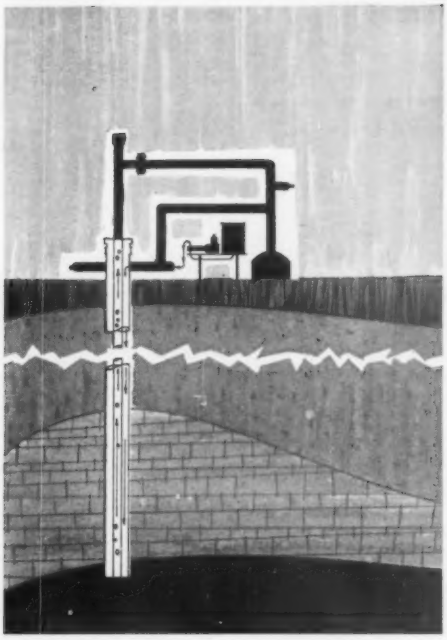

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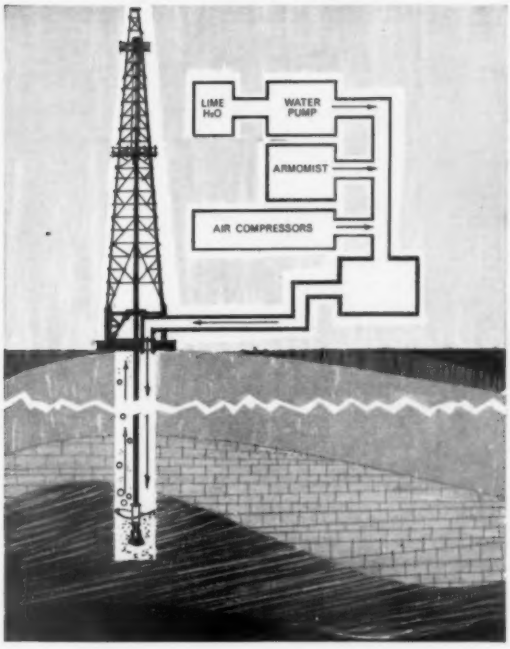

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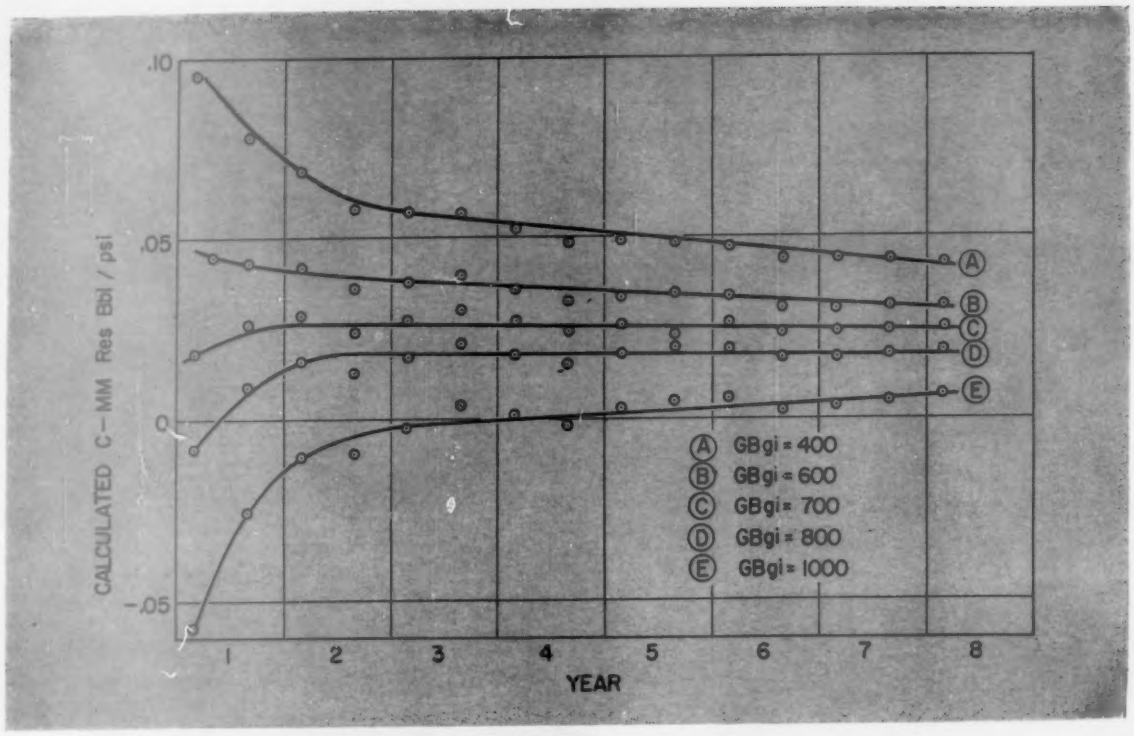

Fig. 2. Calculated as a function of time at n = 8 for gas reservoir.

ever, if the aquifer is bounded and the boundary effect has been felt by the reservoir during the history being studied, it can be observed in the plot of C vs time. When the limitation becomes effective on the reservoir, C will begin to decrease at a constant rate regardless of the value of N or G selected.

When $\overline{C}$ and $\overline{N}$ or $\overline{G}$ have been established, predictions can be made in the manner usually applied to the material balance — unsteady state equations. In the case of a limited aquifer, the influx constant becomes $\overline{C} = \overline{C} + \Delta C$ where ΔC is a function of time established from the C vs time plot.

The simplified method has been applied to four gas reservoirs and one oil reservoir. The results compared to those of other methods are shown in Table 1.

Example Calculations

Table 2 shows the pressure-production history of a gas reservoir. This is a reservoir whose gas has remained above the dew point throughout production history. There has been no water production. Also shown in Table 2 are the computations of C at assumed values $GB_{gi} =$ 700,000,000 reservoir barrels and n = 0.8.

Fig. 2 is a plot of C vs time for various values

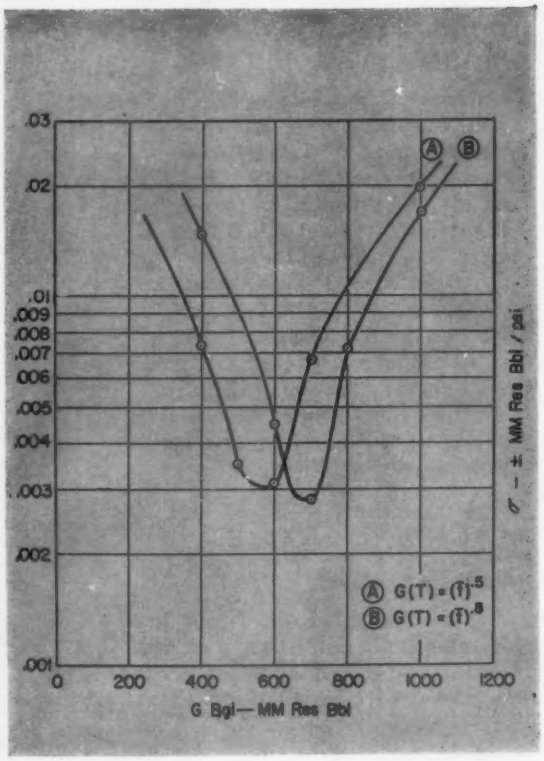

Fig. 3. Standard deviation on C_m for gas reservoirs as a function of original gas in place.

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of GB_{gi} from 400,000,000 to 1,000,000,000 reservoir barrels at $n = 0.8$. It can be seen from Fig. 2 that the optimum value of GB_{gi} lies between 600,000,000 and 700,000,000 reservoir barrels.

Table 3 shows the calculation of the standard deviation on C_m at assumed values $GB_{gi} = 700{,}000{,}000$ reservoir barrels and $n = 0.8$, and Fig. 3 is the plot of standard deviation vs GB_{gi} at values $n = 0.5$ and $n = 0.8$. This plot indicates the optimum value of gas in place to be 670,000,000 reservoir barrels. The optimum influx constant is 28,700 reservoir barrels per psi.

Table 3. Calculation of Standard Deviation on C_m at $G \times B_{gi} = 700 \times 10^6$ and $n = .8$ for a Gas Reservoir.

Total prod. time (years)	C	$(C_m - C)$	$(C_m - C)^2$
1.0	0.0185	0.0071	0.0000503
1.5	0.0263	−0.0007	0.0000005
2.0	0.0289	−0.0033	0.0000109
2.5	0.0243	0.0013	0.0000017
3.0	0.0275	−0.0019	0.0000036
3.5	0.0304	−0.0048	0.0000230
4.0	0.0276	−0.0020	0.0000040
4.5	0.0245	0.0011	0.0000012
5.0	0.0264	−0.0008	0.0000006
5.5	0.0233	0.0023	0.0000053
6.0	0.0269	−0.0013	0.0000017
6.5	0.0241	0.0015	0.0000022
7.0	0.0242	0.0014	0.0000020
7.5	0.0249	0.0007	0.0000005
8.0	0.0255	0.0001	0.0000000
	0.3833		0.0001073

$$C_m = \frac{\Sigma C_i}{n_i} = \frac{0.3833}{15} = 0.0256$$

$$\sigma = \sqrt{\frac{(C_m - C)^2}{n_i - 1}} = \sqrt{\frac{0.0001073}{14}} = \pm 0.00277$$

Nomenclature

- B_g = gas formation volume factor, reservoir bbl/scf.
- B_O = oil formation volume factor, reservoir bbl/STB.
- B_t = total (two-phase) formation volume factor, reservoir bbl/STB.
- C = empirical influx constant, bbl/psi.
- c = compressibility, vol/vol/psi.
- C_m = arithmetic mean of a set of values of C, bbl/psi.
- E = cumulative expansion, reservoir bbl.
- $F(T)$ = a rate function of dimensionless time.
- G = total initial gas in place in reservoir, scf.
- G_p = cumulative gas produced, scf.
- $G(T)$ = a volume of dimensionless time.
- i = an interval in a set; also, a subscript denoting initial conditions.
- k = effective permeability.
- m = ratio initial reservoir free gas volume to initial reservoir oil volume.
- N = initial oil in place in reservoir, STB.
- n = an empirical exponent, dimensionless.
- N_p = cumulative stock tank oil production, STB.
- n_i = number of intervals in a set (corresponds to $\bar{t}$).
- p = pressure, psi.
- r = radial distance.
- R_p = cumulative gas oil ratio, STB.
- R_s = solution gas oil ratio, scf/STB.
- t = time.
- W = cumulative withdrawals, reservoir bbl.
- W_e = cumulative water influx, bbl.
- W_p = cumulative water production, bbl.
- ϕ = porosity, fraction.
- μ = viscosity.
- σ = standard deviation.

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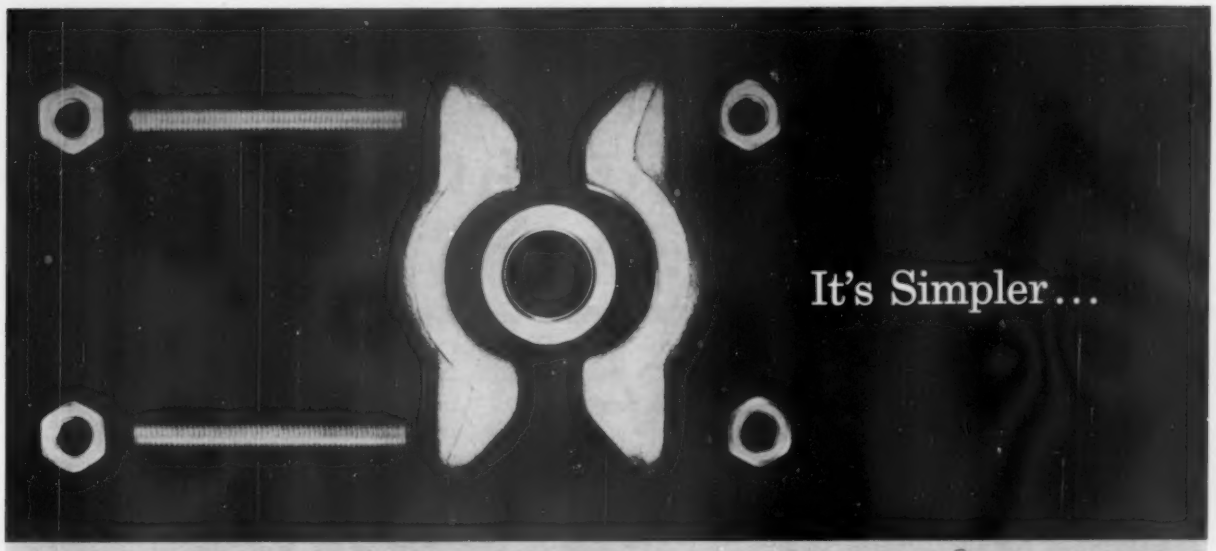
Mr. Stanley is a reservoir engineer with the Pure Oil Co. research center, Crystal Lake, Ill.

■



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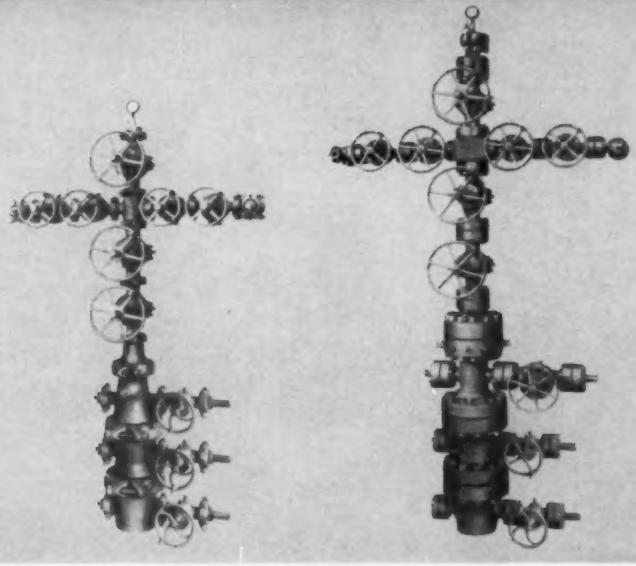

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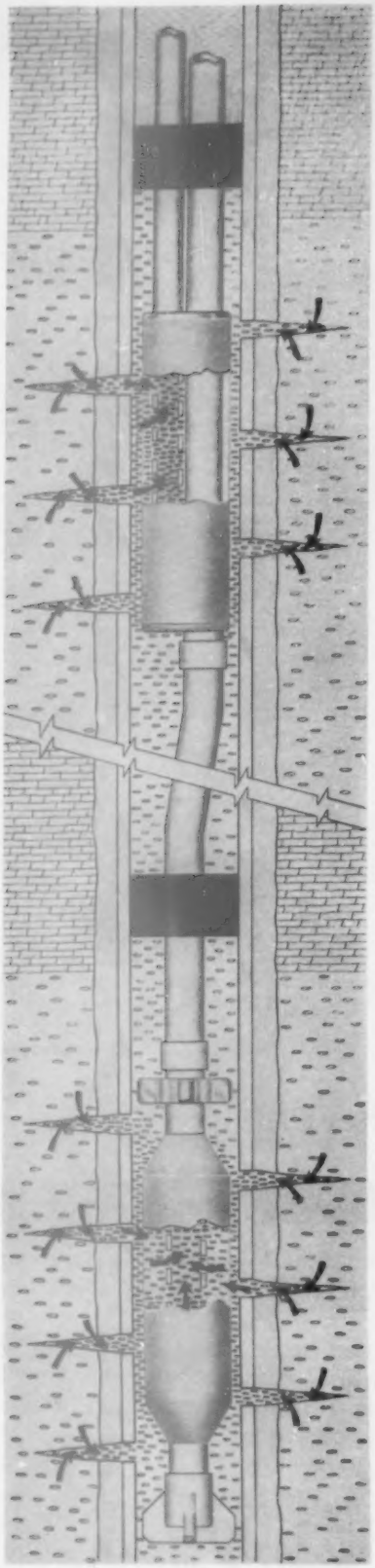


Fig. 1. Here's how Halliburton's new dual sand screen works in a dual completion. The lower unit is a regular single zone sand screen.

Sand Control

A new Halliburton Co. dual sand screen controls sand problems in the upper zone of several South Louisiana dual completions. Technique involves running a regular sand screen opposite the lower zone (Fig. 1) and installing the new dual screen opposite the upper zone. Production from the lower zone is conducted through a parallel tube which is a part of the upper dual sand screen shown in Fig. 1.

The California Co. and Gulf Oil Corp. have used these two types of screens in their completion techniques in dual wells in such fields as Bully Camp, Romero Pass, West Delta, Bay Marchand and Ship Shoal.

Basic construction of both types of screens is identical —an outer layer of consolidated sand held in place around a mandrel of slotted tubing. However, the dual completion screen incorporates dual strings of tubing. One is slotted and receives the production from the upper zone, and the other carries fluid from the lower zone.

The sand screen is the screening medium. Sand produced from the formation tends to diffuse over its entire surface. Sand is an ideal exclusion material because it acts as a natural buffer, is inert and compatible with produced fluids under downhole conditions.

Development of the dual screen was completed late in 1960, some six months after Halliburton introduced the regular screen. Once actual field use of the regular screens established the efficiency of the basic screening mechanism, the company's engineers began work on a dual screen to meet a long-standing problem—what to do with a well that produces sand from two different zones where sand control is required.

Some operators in South Louisiana produce such wells from the lower zone only, because of difficulties involved in placing and producing through mechanical sand control devices opposite more than one zone. Others rely on consolidation treatments in both zones, with varying degrees of success. A few operators control sand entry in the upper zone by restricting production which tends to decrease the amount of sand influx.

Both versions of the Halliburton screens are available in 6-ft lengths. The optimum size is based on detailed studies of the thicknesses of 731 producing zones in South Louisiana.

Two types of sand gradations are presently available for the screens, a 20/40 round Ottawa grade fracturing sand and a mixture with more extreme size gradations. ■

for Dual Completions

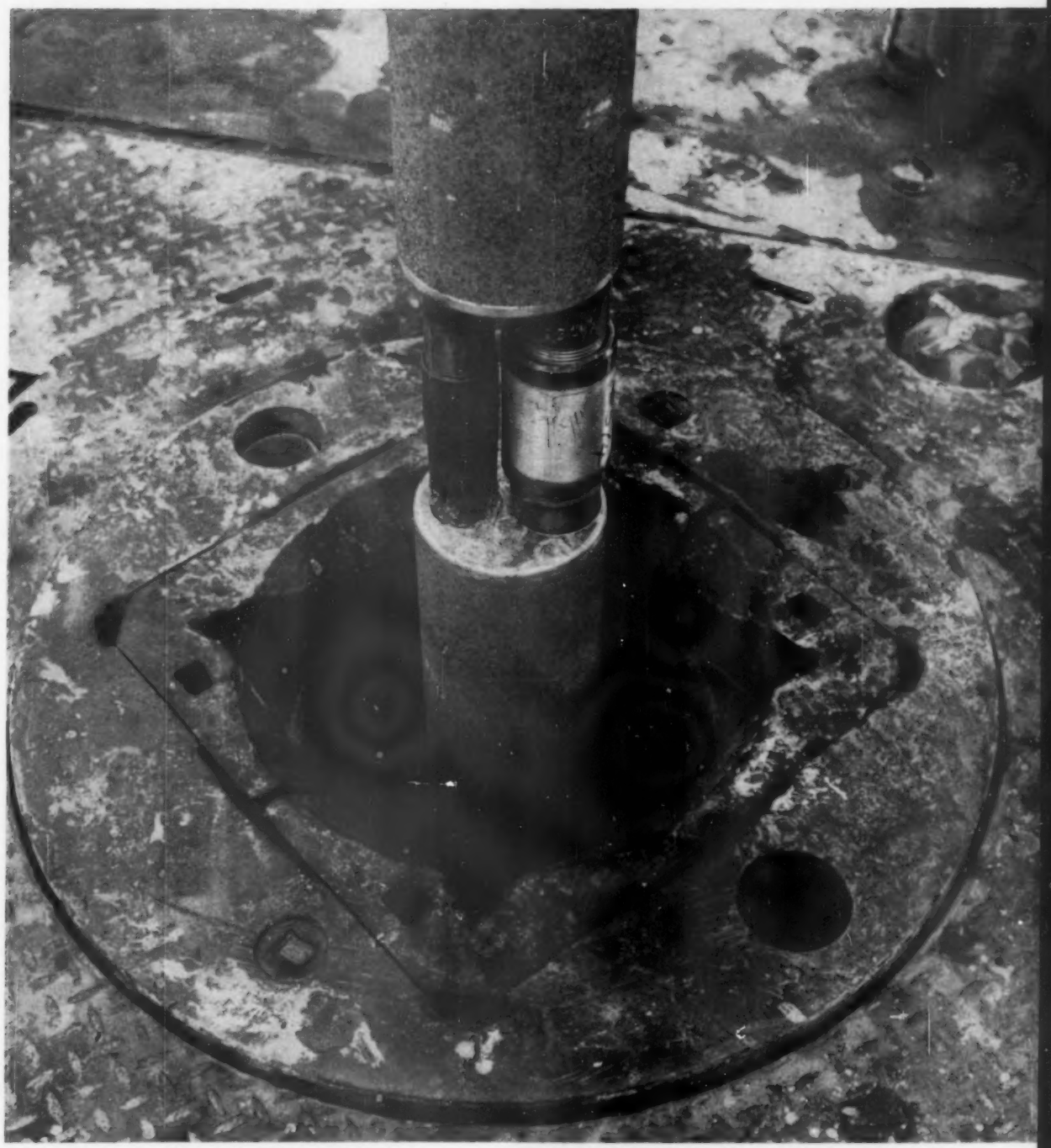
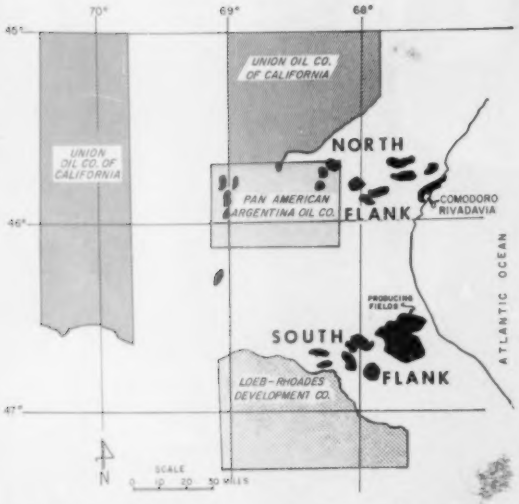


Fig. 2. Six-ft lengths of the dual sand screens are coupled, as shown, going through the rotary table. Left tubing is slotted inside the layer of consolidated sand and takes production from the upper zone. Right tubing handles production from lower zone. Lower zone separated from top zone with a packer.

Argentina Bets Heavy on San Jorge Basin



Comodora Rivadavia area of the San Jorge Basin in south Argentina showing oil producing fields in black and principal development contract areas.

Argentina is putting its hopes for petroleum independence in the giant San Jorge Basin of the southern wind-swept coastal plains better known as Comodoro Rivadavia. In this vast arid basin where temperatures vary from 5 F in the winter to 85 F in the two summer months, exploration and development activity has increased at a fantastic rate since 1958 when the government petroleum agency Yacimientos Petroliferos Fiscales (YPF) first granted development and drilling contracts to non-government and foreign companies. Principal contract holders are: Loeb Rhoades Development, Ltd., Pan American Argentine Oil Co., and Union Oil Co. of California (see map).

Nearly 6000 wells have been drilled in the San Jorge Basin since its discovery in 1907. Some 420 million bbls have been produced and remaining reserves are estimated at about 2.4 billion bbl. Some three trillion cu ft of gas reserves are known and about 1 million cu ft per day is produced. Most of this goes to Buenos Aires located about 900 miles north of the city of Comodoro Rivadavia.

The San Jorge Basin extends from the eastern slope of the Andes Mountains easterly to the Atlantic Ocean, and 200 miles north and 100 miles to the south of the City of Comodoro Rivadavia. Normal fault structures, faulted anticlines and faulted noses are the most commonly-occuring structures in this basin. The sands are lenticular and seldom extend over several locations (23-acre well spacing). These sands are classed as shaly and contain formation waters with salinites varying from 8000 to 18,000 parts per million salts. Each producing well will encounter five or six sands from three to 25 ft in thickness. Porosities range from 16 to 33% and permeabilities up to 800 millidarcys. Reservoirs generally are of a solution gas or depletion type drive. However, several gas cap drives have been found. Oil varies from 18 to 32 deg API gravity with a high pour point. In practically all cases, the crude oil is under saturated.

In both the north and south flanks, seismic and surface studies have located many structures. Producing sands occur from 1500 to 7000 ft deep, dependent upon the location of the field in regard to the basin. Wells are drilled to 5100 ft in 96 drilling hours and with only three bits. Shaly sands and brackish formation water present some logging problems, making it difficult to correlate from well to well because of sand lenticularity. Primary oil recoveries of 20% of

oil-in-place can be expected and is typical of the types of reservoirs generally encountered.

Drilling Practices and Problems

Even though drilling depths are not extreme and the sand and shale sequence drills easily, problems do exist. Gravel beds are encountered in many areas to a depth of 300 ft. Occasionally, boulders are found to 1000 ft. Basaltic sills several ft thick are difficult to penetrate. These usually are associated with cavernous conditions and present lost circulation hazards. In some areas, sloughing shale is a problem, and extreme caution must be exercised when drilling between 2200 and 3000 ft where the shale tends to ball up round tool joints and restrict fluid returns. Additional mud pump pressure to overcome this problem will fracture the formations and mud returns are lost. A day or two is lost in getting the hole back into shape.

To combat this problem, each joint of drill pipe is reamed down and returns are observed carefully for warning signs. Usually, the shale-mud collar lodged around tool joints can be broken by working the pipe up and down while circulating mud until the annulus is cleared.

Drilling rig activity continues to increase at a steady pace. In the north flank at this writing there are a total of 19 rigs running and 40 in the south flank for a total of 59 drilling rigs. Completion rig activity in the south flank numbers 23 rigs and seven in the north flank for a total of 30 completion rigs running.

For the remainder of the year, it is expected that total rig activity in the north flank will remain somewhat steady. But in the south flank where activity is gaining momentum, the total rig count may easily go as high as 100 rigs (both drilling and completion units) and possibly more by the end of 1961.

Completion Practices

An average 5400-ft development well in the Canodon Leon portion of the south flank will take 140 ft of 9⅝-in. surface pipe and a full string of 5½-in., 17-lb production casing. An induction log is run and side wall samples are taken before casing the well. As soon as the casing cement plug bumps bottom, the drilling rig is moved to another location. Under this program, drilling rigs are used to primarily cut new hole on a per-foot basis. Less-expensive completion rigs are used to complete the wells.

The first zone is perforated and tubing is run with a full bore packer to test the well by swabbing. If the test indicates water, the zone is squeezed through the packer which is then reset above the wet zone to test the next productive horizon.

Insofar as possible, all zones are perforated and tested through the tubing to save time. The average well will contain four to five zones to be tested. About six days are required to make all tests. The completion rig is moved to another location when oil begins to flow into the tank battery.

Initial production of the average well is about 300 bbl per day through a ½-in. choke at 75 psi flowing pressure. This pressure declines after about six months of production and the well is then placed on artificial lift, usually beam pumping. This average well will produce for about six years, declining to about 20 bbl per day. When this economic limit is reached, the well may be re-completed in another zone.

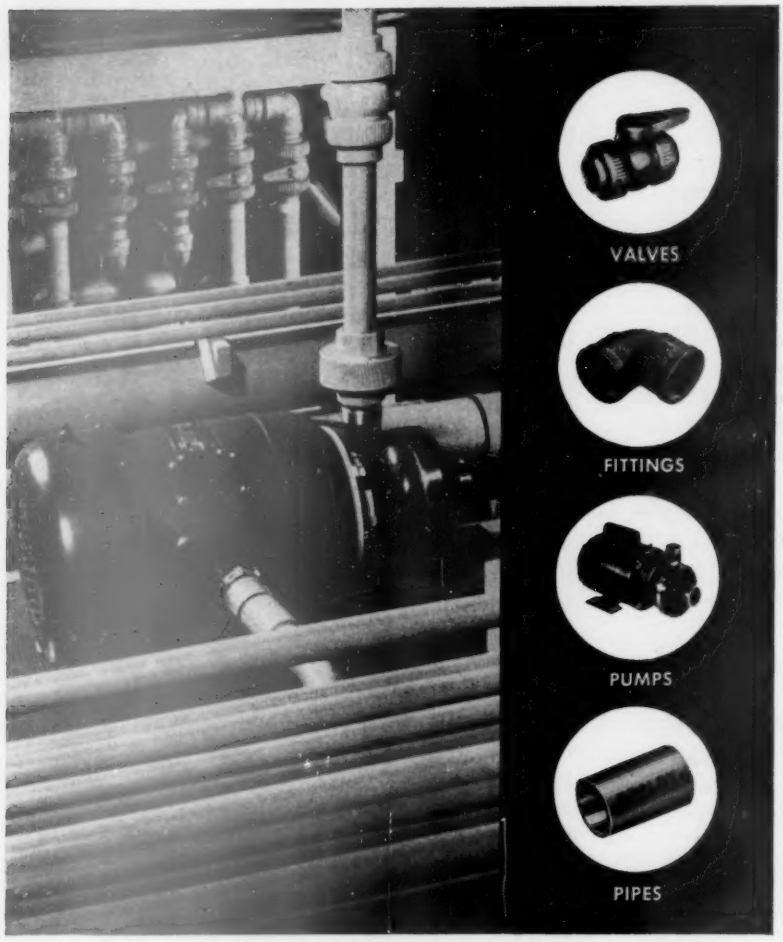
Production Practices

There is nothing especially unique about production problems encountered in the south flank. It has its share of rod partings, pumps wear out, cups cut out, and servicing units are kept busy making these commonly-occurring repairs.

Secondary recovery of oil in the Comodoro Rividavia area has been discussed and argued by oil men for years. The huge reserves and low per-acre ft recovery make secondary recovery extremely attractive. On the other hand, discontinuity and lenticularity of the reservoirs plus the low gravity, undersaturated oil tends to discourage many operators from attempting secondary recovery. Nonetheless, a five-spot pilot flood is being installed by Aquila Compania de Petroleo (Helmerich and Payne, et al) in the Astra area of the north flank. It is anticipated by this time next year the outcome of this project will be known. If successful, there is no question about the installation of quite a number of other pilot projects in both the north and south flank areas.

A Pattern for Others

In spite of the multitude of drilling and production problems, not to mention those of supply and communications, Argentina is successfully and economically exploiting its petroleum reserves so critically necessary to the national economy. No doubt this pattern of development will be followed in other industries and in other countries throughout the world. ■



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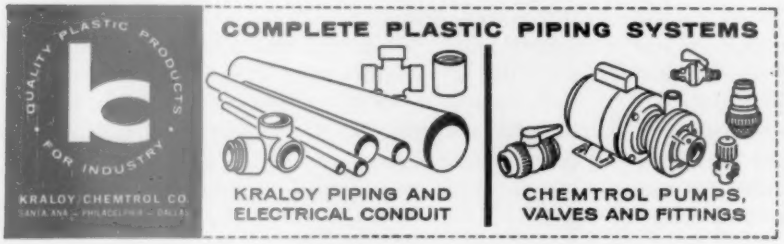
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Woes of Finding Oil Instead of Gas

Once producers shook their heads when they found gas instead of that precious black substance.

Now times have changed radically.

There is still something to be said for finding oil when you are looking for gas, but it can bring a hatfull of headaches.

Take, for example, a recent case involving Shell Oil Co.

In Texas County of the Oklahoma Panhandle gas producing area, Shell was following the state's Corporation Commission rule in drilling one well on each 640-acre section.

A well was located on a tract owned by Mrs. Gloria Meredith, and the idea was for Shell to split the gas royalty between all royalty owners in the entire 640-acre lease.

When the well found oil instead of gas, it touched off a hot legal battle.

Mrs. Meredith contended the well on her property should be granted oil-spacing privileges and asserted she should be entitled to all the royalty from the oil produced. In federal court for the western district of Oklahoma her claim was upheld.

Shell appealed to the US Circuit Court of Appeals at Denver, Colo., which reversed the decision and sent the case back to the Oklahoma Corporation Commission.

The commission stuck to its original ruling . . . one well to 640 acres and split the royalty.

Mrs. Meredith then asked the Oklahoma Supreme Court for a ruling on the matter, and the state justices ruled in her favor.

Shell and the Corporation Commission requested a rehearing, got it and the final decision was reversed.

Several producers have asked for a clarification in such cases, but the commission is sticking to its guns.

Running Tour

G. W. Crickmay will become manager of The Atlantic Refining Co.'s western Canadian region when it is established in October. Crickmay is now vice president and general manager of the Venezuelan Atlantic Refining Co. In anticipation of Crickmay's move, the company has promoted Richard Chadwick-Collins from resident counsel at Caracas to assistant manager of Varco. He will become manager upon Crickmay's departure.

Robert J. Womack has joined Frankfort Oil Co. at its Midland, Texas, district office. He formerly was petroleum engineer for Hanley Co.

Otto Hackel, Roy W. Turner and William W. Whitley have opened an independent consulting firm, Otto Hackel and Associates, at 1414 "Q" Street, Bakersfield, Calif. They formerly were associated with Intex Oil Co.—Hackel as manager of exploration and Turner and Whitley as district geologists in California and the Rocky Mountains, respectively.

John T. Poyner has resigned as reservoir engineer for Texaco Inc. in the Liberty, Texas, district to open his own consulting practice. He will specialize in completions, workovers, lease production problems and reservoir evaluations.

The Atlantic Refining Co.'s reorganization of its domestic producing department includes the following personnel changes:

Tom C. Frick, head of the new natural gas and products division at Dallas, Texas, will serve as acting manager of the eastern region during F. W. (Frosty) Turner's convalescence.

In the southeast Texas-offshore district: J. Frank Crews becomes district production and drilling superintendent; C. R. Tucker, district drilling supervisor; Ralph F. Cox, offshore operations supervisor; and R. L. Trimble, district engineer.

In the new engineering division at Dallas: Vern E. Stepp has been named supervisor of the proration and unitization section; Russ C. Hartman, supervisor of the gas engineering section; Howard A. Koch,

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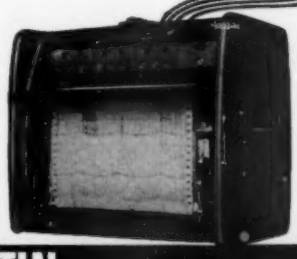

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Jr., supervisor of the reservoir engineering group; J. H. Sullivan, supervisor of the chemical engineering section; J. E. Hellinghausen, supervisor of the drilling group; and Donald B. Helm, supervisor of the production engineering group.

James E. Lloyd has been appointed drilling supervisor of the East Texas district.

In the north Permian district, Charles F. Scott will be administrative supervisor and L. E. Wilson, district drilling supervisor.

For the south Louisiana district, Carl A. Kinney will be district drilling supervisor.

F. C. Williams has been named supervisor of the construction section of the southwest division of engineering and construction.

New executive vice president of Champlin Oil & Refining Co. is Hamilton Rogers who has been an official of Texas Pacific Coal and Oil Co. since 1958.

A. Hamilton Mencher has joined Well Completions, Inc., as director of special services for the Denver-based air and gas drilling firm. He was formerly head of his own public relations company.

Exeter Drilling Co. has appointed Bill Garms as Denver, Colo., representative. He formerly was associated with Garvey Drilling Co.

Vernon M. Turner, a member of Tennessee Gas Transmission Co.'s legal department since 1955, has been promoted to associate general attorney.

Texas Pacific Coal and Oil Co. has promoted Edd Riddle, Jr., to exploration coordinator at Fort Worth, Texas, headquarters and named William Parsons to succeed Riddle as Midland division exploration manager.

Wallace W. March, co-founder of International Drilling Co. and currently a managing director, has retired.

Virgil B. Harris is new president of Producing Properties, Inc., succeeding the late Mac D. Oliver, Jr. The board also named Lionel E. Gilly as senior vice president.

Three of the company's principal engineers, Sidney H. Gottlieb, Kenneth English and H. Eugene Wright, also were elected vice presidents.

Southwest Gas Producing Co., Inc., has promoted George E. Wright to purchasing agent, succeeding the late W. L. Wooley.

Vice president and general manager of Petro-Electronics Corp. is C. C. "Clancy" Pitts, formerly vice president and general manager of Anson Drilling Co., Bogota, Colombia. Petro-Electronics is testing a microwave heating unit developed by its parent, The Raytheon Co., to accelerate flow of oil in wells.

New department managers and consultants at Shell Development Co.'s Houston, Texas, E. and P. research division are:

R. Christy, manager, administration and services, service engineering department, replacing D. E. Broussard who is on special assignment; O. G. Holekamp, manager, exploration research, geophysical department, replacing Dr. F. A. Van Melle who has become a consultant, geophysics; and Dr. C. H. Fay, consultant, physics.

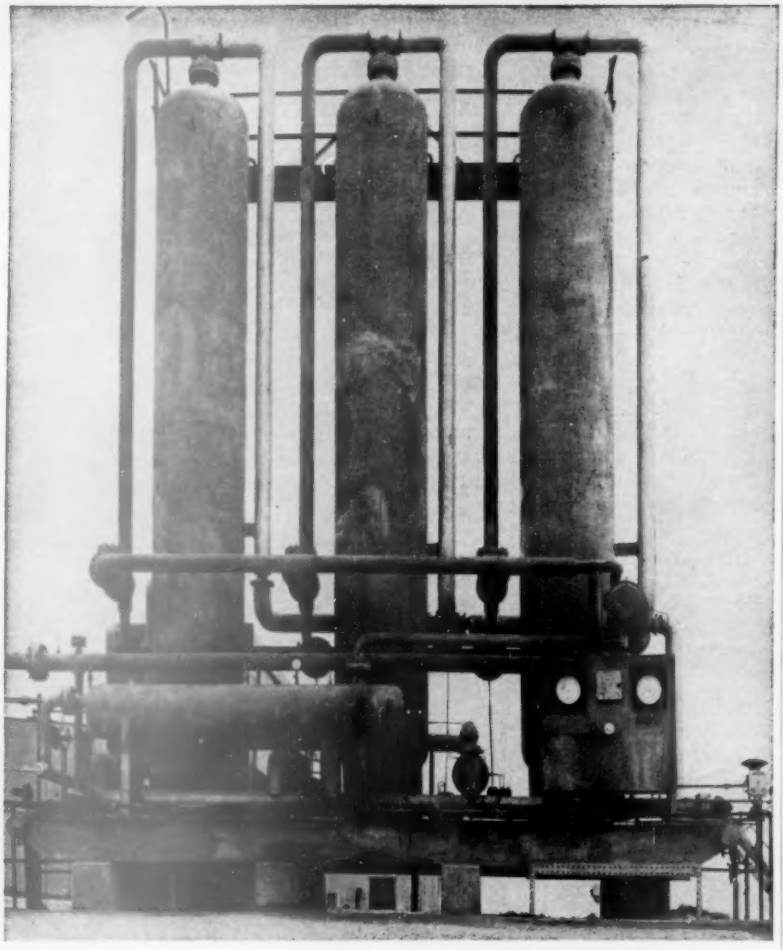
Edward A. Gribi, Jr., most recently with Westates Petroleum Co., has returned to full-time consulting geological practice in King City, Calif.

T. C. Parker has joined the production engineering division of Gulf Research & Development Co., where he will be assigned to the well completion section.

J. Rawles Fulgham, Jr., former head of the credit department of the First National Bank in Dallas, Texas, and presently loan officer in the oil loans division, has been elected vice president, as has Robert T. Present, current head of the credit department.

New production manager of Shell Oil Co.'s Denver, Colo., exploration and production area is P. A. Dennie. He succeeds J. D. Goodrich, recently named director of production research, exploration and production research division, Shell Development Co.

In the company's Houston, Texas, area J. W. Inkster, exploration manager, has left to tour Shell's various exploration and production areas in North America before taking an ex-



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tended assignment at The Hague, Netherlands. He will be replaced for the interim period by E. C. Taber, presently manager of planning in the New York City exploration department. E. J. Strawn, area transport manager in Houston, has begun a special assignment in Houston in the general field of transport for the head office exploration and production organization. R. H. Hurd, former Houston area transport manager, will replace Strawn.

M. King Hubbert of Shell Oil Co. will teach a five-unit lecture course on "Physics of Underground Fluids" from January-March, 1962, in the School of Mineral Sciences at Stanford University.

LeMoyne W. Myers has been appointed technical director and elected vice president of D. R. McCord and Associates, Inc., petroleum consultants in Dallas, Texas. Myers formerly was chief reservoir engineer of Socony Mobil and assistant chief engineer of the Iranian Consortium.

Lion Oil Co., division of Monsanto Chemical Co., has appointed Melvin H. Vaughn as senior geologist and promoted Norman R. Abbott to landman, southwestern exploration region.

In the southern production region, J. F. Reed has been named superintendent of production and W. S. Haun, superintendent of drilling. T. F. Davis, regional production superintendent, continues to supervise both drilling and production operations and J. G. Ragsdale remains regional petroleum engineer.

J. E. Catlin is new assistant superintendent of production in the Shuler field near El Dorado, Ark. J. W. Jean goes from the Arkansas production district to the regional office in Shreveport, La., as petroleum engineer.

William McBee, Jr., has joined the company as regional geologist for the southern exploration region of the production and exploration department.

James L. Wible has joined the drilling and development research division of Jersey Production Research Co. as senior research engineer.

D & P Equipment

Sweetens Sour Gas Streams

Sweet-A-Mine system is said to offer more economical and efficient amine desulfurization. The system will sweeten any sour gas stream from 400 Mcf/d to 50 MMcf/d with virtually no field attendance. Sweet-A-Mine removes hydrogen sulfide and carbon dioxide from gas by: absorbing the acid gases in a solution of monoethanolamine in water; and regenerating the sour amine solution for reuse. A special feature is a reflux condensing coil that increases the efficiency of the regenerating process. The plant is built in two assemblies, absorber and regenerator, which are connected in the field for circulation of the amine solution. Plants too large for skid-mounting of the regeneration assembly are furnished with all accessories. Complete automation equipment is available. *Maloney Crawford Tank and Manufacturing Co.*

Circle number (1) on reply card.

Cleans Walls, Spaces Tubing

Halliburton Co.'s new Combo Spacer-Cleaner combines the features of the casing Recipo wall cleaner and the tubing spacer into one unit. Made of 75 durometer natural rubber, the tool operates efficiently in temperatures up to 300 F. The tool is 5½-in. long and split longitudinally for easy installation around the tubing and is held in place by ¾-in. black metal banding wrapped around the ends, top and bottom. In an open position, the diameter across the cleaning fingers for 2⅞-in. OD tubing is 7 in.; compressed, the OD is 4¼ in. The 2⅞-in. spacer-cleaner can be adapted to 2⅜-in. OD tubing by removing a section 1½-in. wide from the inside diameter. *Halliburton Co.*

Circle number (2) on reply card.

Locates Salt-Water Zones

The Western Co. has developed the Chloritron Log to locate salt-water bearing zones. The log is run in conjunction with a neutron log. The neutron log indicates zones of hydrogen-filled porosity with no differentiation between water and oil. The Chloritron curve is a modified neutron curve which records the effect of chlorine. The relative position of this salt-water curve to the neutron curve allows the formation fluids to be recognized as predominately salt water or fluids free of large amounts of chlorine. The log aids in water-free completions by pin-pointing oil-water contacts and indicating zones of high chloride content. Its use permits investigation of thin oil columns between zones of high salt-water content. It can be used in either new or old wells. *The Western Co.*

Circle number (3) on reply card.

Improve Pumping Power Factor

A line of 830-v outdoor capacitors rated from 2 through 6 kvar is available from Westinghouse Electric Corp. for oil field pumping installations. They supplement the present line of 240, 480, and 600-v instruments. The capacitors provide power factor improvement for high-voltage motors. Applied on the load side of the motor starter, they do not require a separate switch, resulting in minimum installed cost per kvar. They have an aluminum case for permanent protection against corrosion and weather. Included is a 48-in., 4-conductor neoprene cable with watertight bushings. *Westinghouse Electric Corp.*

Circle number (4) on reply card.

Thermoelectric Generator

Primarily designed for remote unattended field instrumentation is an 8-w thermoelectric power generator that will operate from natural gas, propane or butane. Initial applications are expected in the operation of valves on transmission lines or production facilities and for cathodic protection of buried or submerged metal. The unit contains no moving parts. No housing or special enclosure is required as the generator's burner is completely free from wind blowout. The unit weighs 65 lb and is 12 in. wide by 17 in. high. In addition to the more commonly available sources of fuel, these generators can be adapted to use any combustible fuel, waste heat and steam or solar heat. *Texas Instruments Inc.*

Circle number (5) on reply card.

Helicopter Has Boat Hull

A gas turbine-powered, boat-hulled helicopter which carries eight passengers at speeds of more than 100 mph with a minimum of noise and virtually no vibration has been introduced for transportation of crews between drill rigs and shore bases. The S-62 is powered by the General Electric CT-58 engine and is certificated by the Federal Aviation Agency for both land and water operation. In addition to crew changes, it is suited for emergency

PIPE
FORMATION
CASED HOLE
Amplitude curve of
free pipe
up the hole
Good pipe bond,
good formation bond
Good pipe bond,
good formation bond
Poor pipe bond,
unknown formation bond
Good pipe bond,
poor formation bond

WELEX FIRST AGAIN!

Introducing . . .

a cement bond log that reliably logs both sides of the cement sheath

The new Welex Acoustic Cement Bond Log does the most complete job in the business. It "sees" the **formation acoustic bond** as well as the pipe acoustic bond. It works equally well in hard rock country, sand or shale.

Other logs show the pipe bond all right, but nothing about the formation bond. And they work well only in soft formations at that. Pretty limited. Not much to base a completion job on.

Using the Welex system, evaluation of the pipe and formation bond is possible in many areas with only the pipe and formation amplitude curves run in the cased hole. Under certain conditions, especially in hard rock country, the Welex Cement Bond Log employs three acoustic amplitude signals: one for the pipe, one for the formation after casing is set, and one in the open hole for formation evaluation before casing is set. A caliper log in the open hole can be run concurrently to provide auxiliary data.

Proper evaluation of the two — or three — curves locates precisely the area of the poor bond — whether pipe or formation. If squeezing is necessary, the logs tell you exactly where. The reliability of the new Welex Cement Bond Log has been proven in numerous tests.

It is a fact that communication can occur behind the cement even when the pipe bond is good. This condition can lead to costly remedial work. By accurately logging **both sides** of the cement sheath, the new Welex Log can now save thousands of dollars per well. Let the man from Welex show you.

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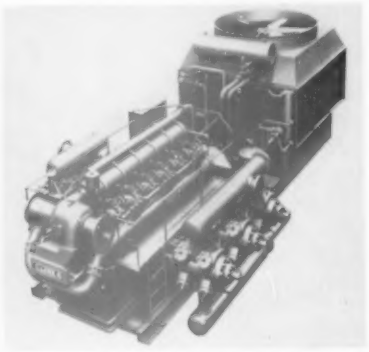
General Offices: 1728 Old Spanish Trail, Houston, Texas

delivery of spare parts, offshore seismograph work, inspection and survey flights over water or swampy areas and rapid transfer of executive or engineering personnel from one facility to another. *Sikorsky Aircraft.*

Circle number (6) on reply card.

Compressor Has Flexibility

The Clark VeePac is a packaged or stationary gas-engine-driven compressor built for field service. It features compactness, cylinder flexibility, balance and dependability. The V-type, 2-cycle turbocharged gas engine may be equipped with



compressor cylinders on one or both sides of the crankcase. A complete 1000 bhp engine-compressor, including radiator and all accessories, can be placed on a skid 35 ft long. The 2-cycle design with fewer moving parts, extra heavy construction and conservative rating is said to assure long periods of reliable service with ample reserve capacity for temporary overloads. The VeePac is furnished as a completely pre-engineered package in two sizes, with 10 and 12 power cylinders rated at 825 and 1000 bhp. *Clark Bros. Co., Div. of Dresser Industries, Inc.*

Circle number (7) on reply card.

Warns of Entrained Air

McCord Corp. offers the new A32156 safe level sight feed for use on Model 55 force feed lubricators. The device acts as a safety feature giving warning of entrained air which can stop oil feeding of the lubricator. The sight feed provides quick priming without the necessity of disconnecting the oil line and permits servicing the lubricator feed without disturbing the sight feed glass. It acts as an air filter chamber as long as the oil level can be seen in the glass. When the oil level decreases in the sight glass, it is a warning that there is excessive aeration in the oil. *McCord Corp.*

Circle number (8) on reply card.

Motor Valve Controls Heater

Heater control systems consist of a temperature controller of some type and a valve to control the rate of fuel gas flow into the heater fire box. Off-on burner fuel control permits temperature to vary over too great a range for most processes; thus, the fuel must be throttled to the burner to maintain the constant temperature required. The Parquip P-5200 valve is designed particularly for such service; the diaphragm is large and has an adjustable spring top. Stainless steel stem is sealed with a lubricated "O" ring. With a 1-in. port, body is available in 1 and ¾-in. pipe size. Rated working pressure is 300 psi. *Parks Equipment Co.*

Circle number (9) on reply card.

Jet Basket Catches Cuttings

The new Kirby boot jet basket has been developed to catch milling cuttings when milling out bridge plugs, cement retainers and production packers. The basket consists of an upper sub mandrel, cylindrical boot with an inner screen around mandrel, and lower jet sub. When positioned in the drilling string above the mill or bit, a jetting action is developed by the recirculation of drilling fluid through the boot sleeve. This jet action creates a suction at the top of the boot which pulls cuttings from the return stream into the basket. *K & G Oil Tools and Service Co., Inc.*

Circle number (10) on reply card.

Drill Collar Compounds

Two additions to the Jet-Lube line of thread compounds are: lead base drill collar compounds containing 50, 55, 60 or 65% lead as specified; and zinc base tool joint compounds containing 40, 50, 55 or 60% zinc as specified. Both series of compounds employ pure metallic powders dispersed in a grease vehicle meeting specifications of API Bulletin 5A2. These compounds are conditioned to be fully brushable over all temperature ranges. *Jet-Lube, Inc.*

Circle number (11) on reply card.

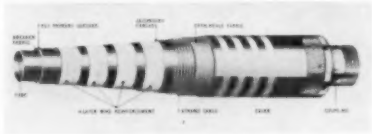
Controls Run-away Engine

A patent has been issued to the Waukesha Motor Co. for a new safety control valve described as an overspeed air shutoff valve for internal combustion engines. It operates on the principle of an over-center positioned lever, spring-loaded to allow the volume of air flow acting on a butterfly to trip or move the butterfly lever past center. The spring closes the valve tightly, shutting off the air supply to the engine. Normally the control is set to trip 100 to 150 rpm above the regular high idle speed, but it is completely adjustable. *Waukesha Motor Co.*

Circle number (12) on reply card.

Rotary Hose Has Long Life

An exceptionally strong and durable rotary drilling hose has been developed by Hewitt-Robins. Designed primarily for deepest drilling depths where great pressure, heat and abrasion cause normal hose failure, the MC-560 hose has 4 layers of single strand steel wire reinforce-



ment instead of the usual 2 layers. Protecting blanket of rubber and fabric permanently positions each wire, cushions against flexing-shock, and insulates against abrasion and moisture penetration. Built-in coupling has no protruding parts, eliminating snagging. Hose comes in three sizes — 2½, 3 and 3½-in. bores — with lengths as ordered up to 60 ft. *Hewitt-Robins.*

Circle number (13) on reply card.

V-Belt Sheaves

The Fabriform V-belt sheave consists of an outer rim welded to a web and gusset unit which in turn, is welded to the hub. For high structural strength, the entire sheave is fabricated of rolled or forged steel plate which is free from inclusions or voids which may be present in a casting. The Fabriform is lighter and has a lower moment of inertia to reduce loading on the pinion shafts of the driven unit. The Fabriform is particularly adaptable to temporary power transmission applications such as drilling mud pumps, compressors, conveyors and other types of oilfield machinery. These sheaves are available in sizes from 44-in. pitch diam with 10 D grooves to 72-in. pitch diam with 20 D grooves. They are furnished with quick-detachable hubs. *Ideco Div. of Dresser Industries, Inc.*

Circle number (14) on reply card.

Literature

Small Structures Pictured

A 6-pager illustrates pre-engineered metal buildings designed to meet small building requirements. The brochure gives complete specifications of the self-supporting A and AL series and Standard Shed buildings and pictures applications ranging from field offices to utility sheds. *The Parkersburg Rig and Reel Co.*

Circle number (15) on reply card.

Protective Coating Described

Plasite No. 7111 is a high-resistant, heavy-build, protective coating primarily for use as a tank lining for fuel and solvents—a cross-linked epoxy-phenolic formulation with a high ratio of phenolic and cured with an alkaline curing agent. Its physical specifications, zone of usage, chemical resistance and application procedures are described in a technical bulletin. *Wisconsin Protective Coating Corp.*

Circle number (16) on reply card.

Progressive Automation

A booklet explains progressive automation of production. Basis of the progressive program is consolidation of leases and automatic control, with each system designed to meet economical and physical characteristics of the individual lease. A system is designed in units, with units added according to master plan until entire lease is automated. *The Ralph M. Parsons Co.*

Circle number (17) on reply card.

Dual-Zone Pump Systems

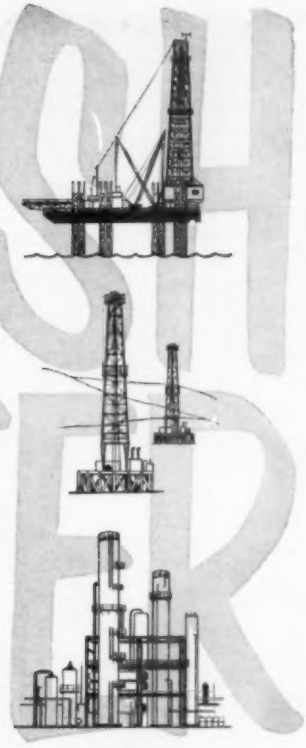
Simplified systems that produce both zones from the same well bore without commingling fluid are the subject of new literature. These systems permit either or both zones to be flowed, pumped, vented or treated as necessary for efficient production. When both zones are pumped, a single rod string and pumping unit is used. The 8-pager includes detailed selection chart with pertinent information and parts list for the various systems. *Pacific Pumps, Inc.*

Circle number (18) on reply card.

MPT Catalog-Index

"Mechanical Power Transmission Equipment" is a condensed catalog of many products and a useful index to the manufacturer's trade literature. It covers V-belt, Ultra-V and FHP drives, timing-belt drives, flat belt pulleys, variable-speed drives, cotton card and cotton cleaner drives, motor bases, flexible couplings, bushings, bearings and pil-

FRESH WATER

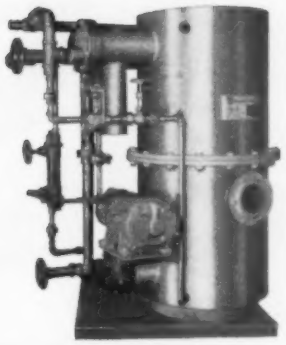


FUEL-FREE . . .

FROM SALT

OR BRACKISH

WATER



Wherever there is a supply of salt or brackish water, AMF-Maxim Aquavap heat recovery evaporators provide a practical, economical way of producing fresh water of purity exceeding U.S. Public Health Service requirements. These compact evaporators operate on engine jacket water or any other hot water source, and thus add nothing to existing fuel cost. They are low in initial cost, inexpensive to maintain and simple to operate, and are delivered as a complete packaged unit ready to install. Capacities range from 150 to 12,500 gallons per day of fresh water.

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low blocks. Each description concludes with reference to a separate bulletin for detailed information, drive selection tables, etc. *T. B. Wood's Sons Co.*

Circle number (19) on reply card.

High-Pressure Valve Data

A publication describes the redesigned V6, a diaphragm-actuated valve designed to handle high-pressure steam, water, gas, oil and air on "open and tight shutoff" applications. A detailed diagram of the valve is included. *Republic Flow Meters Co.*

Circle number (20) on reply card.

Petrofos Uses Detailed

The use of Petrofos (sodium tripolyphosphate) to increase waterflood injection rates and speed secondary oil recovery is outlined in a technical bulletin. It gives physical and chemical properties of the product, tells how it works and contains an appendix of evaluation procedures. *Monsanto Chemical Co.*

Circle number (21) on reply card.

Oilfield Pumps Featured

Rex oilfield pumps, featuring simple design and construction for easy maintenance and service, are the subject of a 4-pager. It carries detailed capacity specifications on 2-in., self-priming, centrifugal pumps. Data on gasoline-powered pumps as well as outboard bearing, electric motor and closed diaphragm pumps is included. *Chain Belt Co.*

Circle number (22) on reply card.

For High Pressure Injection

Flexibility in application of vertical multi-stage can-type pumps to high pressure injection service in oilfield waterflood operations is the subject of an illustrated bulletin. Detailed sectional drawings and zone call-outs of two Hydro-Line pump designs are included. Also described are vertical lineshaft water supply pumps for waterflood operations. These units, it is stated, are capable of lifting water from depths as great as 2000 ft. *Hydrodynamics Div., Peerless Pump.*

Circle number (23) on reply card.

Safety Markings Outlined

"Colors and Methods" is a booklet showing samples of six generally accepted safety marking colors for plants and equipment and exploring in detail their application to hazards most frequently encountered. *The Sherwin-Williams Co.*

Circle number (24) on reply card.

Inorganic Zinc Coating

A 4-page, illustrated bulletin describes the galvanic principle of inorganic zinc protection, both in immersion and non-immersion service. Portions of the bulletin are devoted to a discussion of Carbo Zinc II, with or without topcoats, as a tank lining and a high temperature coating. *Carboline Co.*

Circle number (25) on reply card.

Freeing Stuck Pipe

Pipe-Lax, as an inexpensive way to combat the high cost of stuck pipe, is the subject of new literature. It is described as a new organic chemical concentrate which, when mixed with oil, makes a solution that can soak stuck pipe loose. Case histories are given. *Magnet Cove Barium Corp.*

Circle number (26) on reply card.

Loading Arm Bulletin

A spring-balanced loading arm bulletin features cutaway views of the arm's exclusive riser-joint with its widely-spaced bearing construction, and its exclusive snubber spring that absorbs the arm's upward thrust. Scaled drawings also are included. *Continental-Emsco Co.*

Circle number (27) on reply card.

Target → **Longer Service**

TYPE 30 — Carbon-Manganese fully normalized. For heavy duty where corrosion is not a major problem.

TYPE 40 — Nickel-Molybdenum Alloy. Normalized and tempered. For heavy duty pumping in medium corrosive conditions.

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Deep Drilling Rotary

The new 27½-in. National B-275 rotary for deep drilling highlights an 8-page bulletin. Described are such design and construction features as rectangular housing, matched and lapped spiral bevel pinion and gear, unitized gear-table assembly and cartridge pinion-shaft assembly. *National Supply Div., Armco Steel Corp.*

Circle number (28) on reply card.

Tuffy Products Bulletin

Tuffy polished rods, rod liners and sucker rod couplings are the subject of a new 4-pager. Designed for hard pumping and for wells where repair costs are frequent because of excessive rod and tubing wear, Tuffy products employ a Thermospray process which is described and illustrated. *Harbison-Fischer Mfg. Co.*

Circle number (29) on reply card.

"Fracplan" Discussed

Nomographs, propping agents, procedures, capacities and other data are discussed in a brochure outlining this advanced scientific approach to the problem of planning the most efficient hydraulic fracturing treatment. Examples are given. *Halliburton Co.*

Circle number (30) on reply card.

Engine Safety Control Data

Offering more complete information on all-pneumatic engine safety control systems is a 60-page catalog. It contains full descriptions of a number of complete systems incorporating safety shutdown or warning upon malfunction of measured variables such as temperatures, pressure, levels, speed and vibration. *Fulton Sylphon Div., Robertshaw-Fulton Controls Co.*

Circle number (31) on reply card.

Swivel Joint Price List

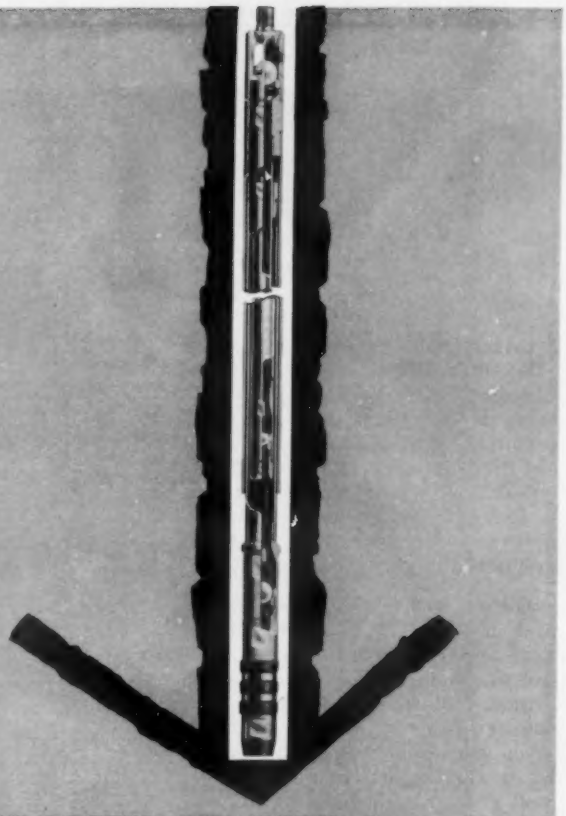
An 8-page price list shows all available OPW swivel joints, including the new swivel joints for use with OPW torsion balanced liquid loaders and OPW floating suction systems. Replacement "O" ring seals are listed on the last page. *OPW Div., Dover Corp.*

Circle number (32) on reply card.

Hydraulic Pumping Units

An 8-pager catalogs the new EOT-Johnston rod-counterbalanced line of hydraulic pumping equipment—with performance data and specifications, as well as field reports. Detailed engineering drawings show the operating principle of the control and slave cylinder. *Engineered Oil Tools, Inc.*

Circle number (33) on reply card.



PUMP SAND-LADEN OIL WITH A HARBISON-FISCHER 3-TUBE ROD PUMP

If you are pumping a recently-fractured well, or from a formation with unusually high sand-laden fluid, a Harbison-Fischer 3-Tube Rod Pump, because it can handle sand and other entrained solids that cause trouble in other pumps, may solve your pumping problems once and for all.

The pump consists of two concentric, loose-fitting tubes (plunger and jacket tube) which telescope over and in a third, stationary tube that serves as the pump barrel. Well fluid in the annular spaces between the three tubes packs off and compensates for the loose fit.

This "fluid seal," the loose-fitting plunger, and a small plunger bore combine to produce sandy fluid efficiently . . . a high-velocity discharge at the bottom of the pump flushes sand into the fluid column after shut-down periods and keeps it in suspension; there's no plunger sticking or galling due to sand in the fluid, and no plunger wear or strain on the rod string.

There are other features, too . . . a no-go ring to position the pump in the seating nipple so that sand accumulation is insufficient to sand in the pump, standard-sized A.P.I. balls and seats, and many more that make the H-F 3-Tube the Best Pump in the Oil Patch for sand, or as an all-round pump.

If sand is a problem with you, find out the advantages of an H-F 3-Tube Rod Pump. Ask your store or one of our 70 field men for details, or write us at P. O. Box 2477 in Fort Worth for literature. No obligation, of course.

HF

"MOST PUMPS IN THE OIL PATCH"

HARBISON-FISCHER

FORT WORTH

Exploration

ALASKA

Interior Department approved St. Elias development contract with Standard Oil Co. of California covering 247,000 acres in the Icy Bay region in the Gulf of Alaska. Standard of Calif. agreed to spend $500,000 and will start a well by January 1, 1962. During each of the following two years, the company must drill a well and spend $250,000.

Oil and gas field maps on a scale of 1 in. = 2000 ft of the Kenai gas field and the Swanson River field are available from the Division of Lands, Department of Natural Resources, State of Alaska, 344 Sixth Ave., Anchorage, Alaska. Price is $1 in cash each. Each map shows well locations and total depths, and will be revised monthly if operations justify.

ARGENTINA

YPF issued three calls for tenders from private oil companies to develop areas in Mendoza, Neuquen and Santa Cruz on a production contract basis. Proposals must be submitted by August 18. The Mendoza offering comprises 200 sq km in an area where YPF reportedly drilled six wells, five of which are productive. In Santa Cruz, a rectangle 40 km long and 8 km wide is offered. One productive well has been drilled in the Neuquen area of about 40 sq km north of the city of Neuquen in the Entre Lomas zone. Bids by local companies include ASTRA and a new Argentine company, Petroleras Argentinas Unidas SA (PAUSA).

CALIFORNIA

Signal Oil & Gas Co. completed an oil discovery five miles west of the Mountain View field in the San Joaquin Valley. The company's No. 1-16 X flowed 65 bbl per day of 30 API gravity oil and 2% water through a 12/16-in. choke from perforations at 10,514 to 10,595 ft.

Buttes Gas & Oil Co. extended gas production through completion of its No. 17 Buttes-Carrol, located 1½ miles northwest of its No. 16 gas discovery well. Area is about two miles southeast of the West Butte Reserve in Northern California. The extension flowed 4.5 million cu ft daily from 4805 to 5018 ft through a ⅜-in. choke.

Off the Santa Barbara coast, Global Marine Drilling Company's drilling ship, the Cuss I, is drilling in 250 ft of water for Standard Oil Company of California. Contract calls for exploration work to take about 30 days.

CANADA

Triple zone discovery was completed by Zapata Petroleum Corp. three miles southeast of the Rosebud Glauconitic field in Alberta Province. Zapata's No. 7-23 CPOG Hussar drillstem tested 1.3 million cu ft per day at 1765 to 1870 ft; the Viking zone at 3610 to 3655 ft tested at the rate of 150,000 cu ft per day along with an oil rate of 100 bbl daily; the Basal Quartz zone at 4295 to 4345 ft tested gas at the rate of 13,000 cu ft per day.

Home Oil Co., Ltd., in the Pendant D'Orielle Bow Island field of Alberta, brought in three new pay zones. Home Oil's No. 7-17 CMG Pendor tested 6.7 million cu ft of gas per day from the Basal Cretaceous at 2785 to 2820 ft. The Basal Colorado at 2442 to 2540 ft flowed 3.5 million cu ft daily. A drillstem test in the Blairmore formation at 2572 to 2800 ft reported a flow of 4 million cu ft of gas daily.

COLOMBIA

Colombia-Cities Service Petroleum Corp. has dually completed its Payoa No. 1 well in the middle Magdalena Valley located 30 miles northeast of Barrance-Bermeja and about 160 miles north of Bogota. Well was tested at five horizons between 6895 ft and 8388 ft where API gravity ranged from 23.1 to 35. Lower zone tested 920 bbl during a 10-hr test. The well is located on the eastern edge of a 75,000-acre block which is part of the two million acres being explored by the company and its associates. Colombia-Cities Service is the operator of this joint venture which includes Ecopetrol, the Colombian government oil agency, Richfield Oil Corp., and Pan-American International Oil Corp., each with 25% interest.

INDIA

ENI (Ente Nazionale Idrocarburi), the Italian oil group, and the Indian Government are negotiating for exploration and exploitation of petroleum in Gujerat and in Uttar Pradesh.

From the Bureau of Petroleum Information of India comes this specific information about areas opened to private industry. Interested oil companies can get details from the government.

The first category consists of areas which are open for grant of licenses and leases on a negotiated basis for operation by private parties and includes the areas: (1) Jaisalmer-Bikaner-Amritsar belt, (2) Swilak Hills, (3) Western portion Gangetic Plain, (4) Central portion Gangetic Plain, (5) East Ganga Valley, (6) parts of W. Bengal and Orissa, (7) certain areas of the Madras/Visakhapatnam coastal sedimentary belt, (8) and parts of Kerala-Cape Comorin area.

The second category includes areas which are open for grant of licenses and leases on a negotiated basis to private parties in participation with the Oil and Natural Gas Commission. This includes: (a) the Kutch Saurashtra sedimentary belt, (b) the Jammu-Punjab-Uttar Pradesh foothills and plains and, (c) the Mesozoic tertiary sedimentary basin of the east coast of Madras.

LOUISIANA

Shell Oil Company recently discovered oil under Barksdale Air Force Base near Shreveport on its 3624-acre lease which it acquired last December from the Government for $3,865,000. The initial well tested 278 bbl oil per day; a second well, dually-completed, tested 127 bbl oil daily and 2.6 million cu ft of

gas per day. Two wells were being drilled at last report. Shell's leases are in two tracts, separated by two other tracts leased to other companies. All four tracts offset production in the Sligo field near the Air Force Base.

OKLAHOMA

New interest has been focused on the Eastern part of the state where Paul Denton has found oil in the No. 1 Henry Williams, located over a mile northeast of the old Striker field in Wagoner County. In cleaning out hole, operator recovered oil estimated at about 10 bbl per day from the Upper Dutcher formation at 837 to 855 ft. After fracture treatment, the well pumped 30 bbl per day.

OREGON

Shell and Gulf were granted nonexclusive exploratory permits by the Oregon Land Board covering 600,000 acres of tidelands. These are the first permits so granted under a new Oregon leasing law. Although Standard Oil Co. of California and Humble Oil and Refining Co. were represented at the hearings, neither company indicated any immediate plans to file for permits. After August 9, the Board will have authority under the new law to lease blocks of tidelands for exploratory drilling.

TEXAS

Bayview Oil Corp. made a significant oil discovery in its No. 1 A. R. Eppenauer well located in Section 10 Block 6, H&TCRR Co. Survey of Crane County. The well flowed from the Glorieta formation through perforations 3012 to 3022 ft. The well potentialed for 227 bbl oil per day on 20/64-in. choke; GOR:589 cu ft per bbl; oil gravity 42.8 deg API. The San Andres was cored from 2055 to 2265 ft with good oil shows throughout the section. The Eppenauer Well No. 1 will be dually completed in the San Andres zone. The confirmation test, a diagonal offset to the west, A. R. Eppenauer "B" No. 1 well, located in Section 7, same block and survey, has been completed as a flowing San Andres oil producer through perforations 2066 to 2088 ft. This well produced 163 bbl oil in 22 hours on 10/64-in. choke after acid treatment. The Glorieta formation was cored from 2960 to 3035 ft with good oil shows. This well will be dually completed in the Glorieta zone. Bayview holds leases on approximately 1000 acres in the area.

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What's doing in Drilling

Deep Well Costs $5.41 per Inch

Bob Parker, president of Parker Drilling Co. showed a group of business men some of the deep drilling going on in Oklahoma. He took the executives to visit one of the company's big rigs drilling a deep well in Washita County for Humble Oil & Refining Co. At the time of the visit, the well was drilling below 17,000 ft and expenditures to that depth already amounted to $1,088,000. Doing a little arithmetic, he pointed out this was equal to about $65 per foot . . . or $5.41 per inch!

A second well scheduled for 20,000 ft is expected to cost ultimately more than $2 million. Parker is drilling it in the same area for Continental Oil Co.

Canadian Producer Sells Rigs

Pennant Drilling Co.. Ltd., the contract drilling division of Canadian Homestead Oils Ltd.. has been sold to Clinton E. Wright and Floyd M. Stevenson of Denver. Colo., for $750,000. Five rigs and related equipment are involved. E. H. LaBorde, president of Canadian Homestead, in making the announcement, stated the drilling division operated at a loss of $250,000 during its fiscal year ending May 31, 1961. Purchasers paid $450,000 down and the remainder will be paid in installments.

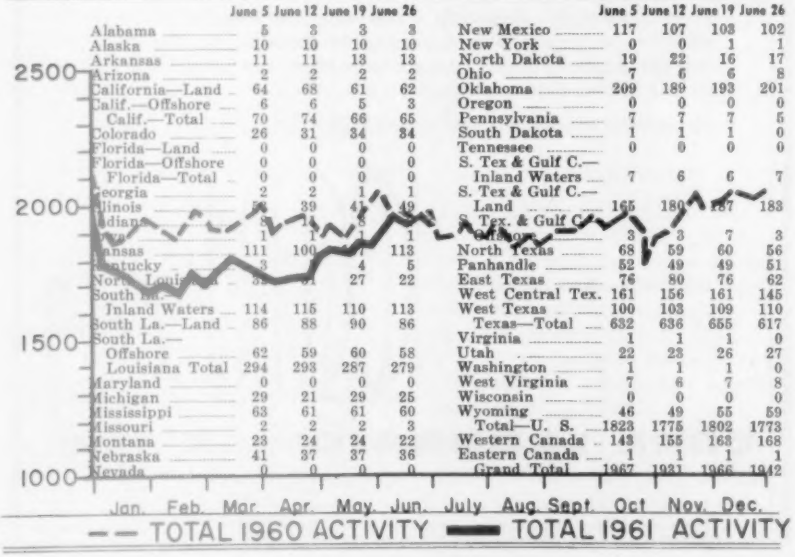
Good Drill String Life In Air Drilling

In Pennsylvania where Delta Drilling Company pioneered and proved air drilling, the company also has experienced exceptional life in drill pipe. Delta's Rig 34 in the past seven years has drilled 71 wells in this hard rock country for a cumulative total of 473,336 ft with an 8000-ft string of 4½-in. 16.60-lb Grade E drill pipe. National Supply Co., who supplied the Spang pipe and 6-in. OD full hole double shrink thread tool joint, took a 2-ft section of the pipe with tool joint into the laboratory for examination. Findings showed uniform wear and concluded that with continual slow rotative speeds (around 65 rpm) and adequate drill collars (50,000 lb) to maintain the string in tension, much more life remains in the string.

Rotary Rigs Operating in Oil Fields of United States and Canada

As reported to American Association of Oil Well Drilling Contractors by Hughes Tool Company.

	June 5	June 12	June 19	June 26
Alabama	5	3	3	3
Alaska	10	10	10	10
Arkansas	11	11	13	13
Arizona	2	2	2	2
California—Land	64	68	61	62
Calif.—Offshore	6	6	5	3
Calif.—Total	70	74	66	65
Colorado	26	31	34	34
Florida—Land	0	0	0	0
Florida—Offshore	0	0	0	0
Florida—Total	0	0	0	0
Georgia	2	2	1	1
Illinois	53	39	41	49
Indiana	8	14	5	6
Iowa	1	1	1	1
Kansas	111	100	97	113
Kentucky	3		4	5
North Louisiana	33	31	27	22
South Ark.—				
Inland Waters	114	115	110	113
South La.—Land	86	88	90	86
South La.—				
Offshore	62	59	60	58
Louisiana Total	294	293	287	279
Maryland	0	0	0	0
Michigan	29	21	29	25
Mississippi	63	61	61	60
Missouri	2	2	2	3
Montana	23	24	24	22
Nebraska	41	37	37	36
Nevada	0	0	0	0
New Mexico	117	107	103	102
New York	0	0	1	1
North Dakota	19	22	16	17
Ohio	7	6	6	8
Oklahoma	209	189	193	201
Oregon	0	0	0	0
Pennsylvania	7	7	7	5
South Dakota	1	1	1	0
Tennessee	0	0	0	0
S. Tex & Gulf C.—				
Inland Waters	7	6	6	7
S. Tex & Gulf C.—				
Land	165	180	187	183
S. Tex. & Gulf C.				
Offshore	3	3	7	3
North Texas	68	59	60	56
Panhandle	52	49	49	51
East Texas	76	80	76	62
West Central Tex.	161	156	161	145
West Texas	100	103	109	110
Texas—Total	632	636	655	617
Virginia	1	1	1	0
Utah	22	23	26	27
Washington	1	1	1	0
West Virginia	7	6	7	8
Wisconsin	0	0	0	0
Wyoming	46	49	55	59
Total—U. S.	1823	1775	1802	1773
Western Canada	143	155	163	168
Eastern Canada	1	1	1	1
Grand Total	1967	1931	1966	1942



Death Takes Drilling Leaders

The month of June may have been a little brighter for nation-wide drilling activity, but it was one of sorrow for many. Perhaps at no single month . . . or week . . . has the drilling industry lost two of its giants . . . pioneers that helped establish contract drilling as an industry.

On June 11th, Charles L. Rowan, board chairman of Rowan Drilling Company, Fort Worth, Texas, died after a long and colorful career in contract drilling. He was the brother of Arch H. Rowan, founder of Rowan Drilling Company and the third president (1944) of the American Association of Oilwell Drilling Contractors.

Another severe blow shook the drilling industry on the following day . . . June 12th . . . when George P. Livermore, head of Livermore Drilling Company of Lubbock, Texas, was killed in an automobile accident near Guthrie, Texas. In the mid-1940s, he drilled the first producing oil well in Chile, which at that time was the southern-most well ever drilled. He organized his drilling firm in 1936 and was active in drilling work until the time of his death. He was elected 1959 national vice president of the AAODC and at the 1960 annual AAODC meeting was presented the Meritorious Service Award for that year.

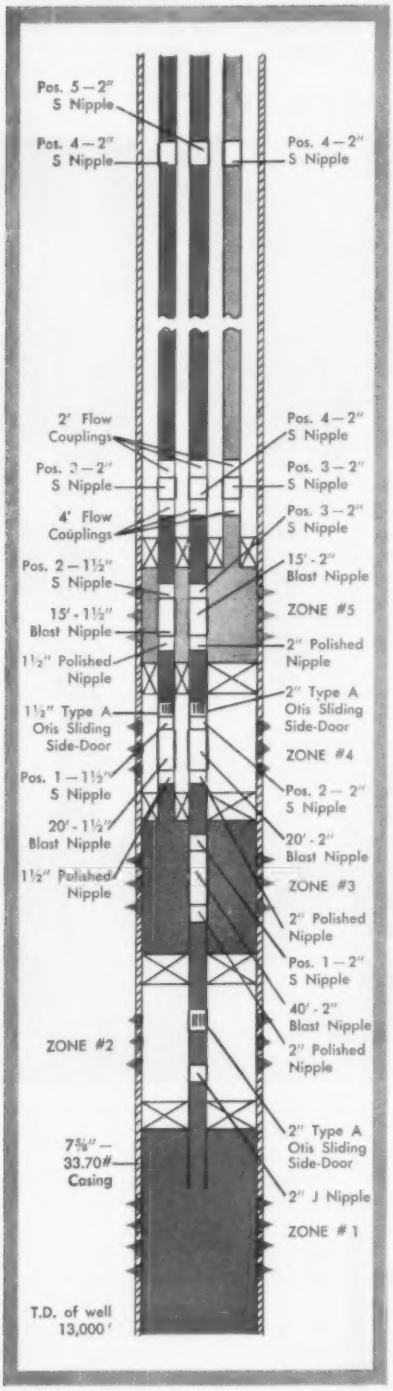
Just one month earlier to the day . . . on May 12th . . . Bob Rose, president of Drilling and Exploration Co. died unexpectedly in Dallas, Texas.

CUSS 1 Stripped of Special Gear

Global Marine Drilling Company's Cuss 1 is back on conventional water drilling after successfully coring a test well for the Mohole project in 12,000 ft of water. The floating drilling ship currently is working off the coast of Santa Barbara, California, for Standard Oil Co. of California. The vessel was stripped of special Mohole project equipment . . . four outboard motors to position the vessel . . . the huge guide shoe or funnel

OTIS PRODUCTION NEWS

Volume II, Number 1 **Otis Engineering Corporation • Dallas** *Production Equipment and Services*


Pos. 5 — 2" S Nipple
Pos. 4 — 2" S Nipple
Pos. 4 — 2" S Nipple
2' Flow Couplings
Pos. 4 — 2" S Nipple
Pos. 3 — 2" S Nipple
4' Flow Couplings
Pos. 3 — 2" S Nipple
Pos. 2 — 1½" S Nipple
15' - 2" Blast Nipple
15' - 1½" Blast Nipple
ZONE #5
1½" Polished Nipple
2" Polished Nipple
1½" Type A Otis Sliding Side-Door
2" Type A Otis Sliding Side-Door
ZONE #4
Pos. 1 — 1½" S Nipple
Pos. 2 — 2" S Nipple
20' - 1½" Blast Nipple
20' - 2" Blast Nipple
1½" Polished Nipple
ZONE #3
2" Polished Nipple
Pos. 1 — 2" S Nipple
40' - 2" Blast Nipple
ZONE #2
2" Polished Nipple
2" Type A Otis Sliding Side-Door
7⅝" — 33.70# Casing
2" J Nipple
ZONE #1
T.D. of well 13,000'

Copyright 1960 Otis Engineering Corporation

Alternate Zone Triple Completion Shows Economic Advantages of Using Otis Equipment and Wire Line Services

LAFAYETTE — This offshore, multiple-zone gas well, located off the coast of Southern Louisiana, illustrates the economic advantages of using Otis sub-surface flow control equipment and wire line services.

The cost of the installation, including the tubing safety valves, sleeves, nipples, and other Otis sub-surface equipment as shown in the accompanying diagram, totaled slightly under $12,000 — or about $65,000 less than what it would cost to move a workover rig onto the well to deepen it and recomplete the lower zones, had the well been drilled and completed differently. As equipped, this well can be produced until all five zones have been depleted, with only occasional wire line service to permit production from each of the different zones.

T.D. of the well was approximately 13,000 feet with five different zones of potential production below 12,600 feet. When called to engineer the completion, Otis specialists were asked to design an installation that would permit alternate production of three of the zones through the long string and one through each of the other strings, or two zones through the long string and two through the intermediate string, with the top zone to be produced through the short string.

Two single packers were used to isolate zones 1 and 2 and a Type A Otis Sliding Side-Door and Type J Otis Landing Nipple were made up in the tubing between the two packers. This arrangement will permit the bottom zone to be produced first through the long string, and then zone 2 by setting a Type PJ Otis Plug Choke in the landing nipple and shifting the sleeve in the Sliding Side-Door®. The Type PJ choke is designed to hold pressure from either direction.

A blast nipple with a Position 1 Type S Otis Landing Nipple above and a polished nipple below was designed into the long string opposite zone 3. This is the zone to be produced through the intermediate string. In the event flow from zone 3 should cut through the blast nipple, the landing nipple and polished nipple will be used to pack off the hole and permit continued production of either of the lower zones through the long string. The landing nipple above the blast nipple may also be used to land a plug choke in the event both lower zones deplete sooner than anticipated and the operator decides to produce zone 4 through the long string.

Otis sliding side-doors were designed into both the intermediate string and the long string between the packers isolating zone 4. This will permit selective production of that zone through either string of tubing. S nipples, blast nipples, and polished nipples were also made up on both the intermediate and long strings opposite zone 4 to provide the tubing with the same protection as described for zone 3.

In that this was a gas well, S nipples with flow couplings above and below were made up in all three strings of tubing, immediately above the top packer, to accommodate Type FS Otis Tubing Safety Valves. This provided Storm Choke® protection for each string. By locating the safety valves just above the top packer, the operator will be able to carry on a corrosion inhibitor program without pulling the safety valves. S nipples were also located in each string approximately 1,500 feet from the surface for plugging purposes until gathering lines could be laid.

This Otis-engineered completion was designed to provide the ultimate in economical, versatile, and efficient alternate-zone production. For more information on alternate-zone, multiple completions or for help with any other specific completion problem, call the Otis office nearest you or write Otis, Dept. 1-W, Box 35206, Dallas 35, Tex. Experienced Otis specialists are ready and anxious to provide you with a "packaged" well completion service.

OTIS

Engineering OTIS Corporation

General Offices:

6612 Denton Drive • Dallas, Texas

The Most Efficient, High Pressure Valve Ever Made

W-K-M BALANCED STEM GATE VALVE

The W-K-M Balanced Stem Gate Valve, built to control well pressures up to 20,000 psi, uses the unique and proved parallel-expanding gate principle. A balancing stem permits easy spin-open, spin-shut operation. Turning the handwheel exerts tremendous sealing force at both upstream and downstream seats with positive mechanical sealing in both open and closed positions. Superior performance on highest-pressure wells has made W-K-M Gate Valves the standard of excellence the world around. Futhermore, as added proof, this valve successfully completed "tests more severe than ever attempted on similar equipment" by an independent laboratory. For full information send for bulletin WP 1157 and a copy of "The Crookston Report." ... P. O. Box 2117, Houston 1, Texas.

When So Much Depends on a Valve... Specify W-K-M.

W-K-M DIVISION

ACF INDUSTRIES

that extended through the vessel's midships for distributing the severe forces on the elongated drill pipe . . . and the long string of drill pipe. She will work in 250 ft of water on her 14th assignment in oil exploration during which time some 200,000 ft of hole has been dug in the ocean's bottom.

Kermac Orders Biggest Mobile Rig

Faith in the offshore drilling picture was demonstrated when Kerr-McGee Oil Industries, Inc., of Oklahoma City, announced plans to build the largest mobile offshore drilling barge known. To cost about $6.5 million, Kermac Rig 54 will be built by Avondale Marine Ways at its shipyards on the Mississippi River near New Orleans. It will be capable of operating in offshore waters up to 175 ft deep. Design of the giant unit was developed over a two-year period under the supervision of Paul A. Wolff, chief engineer.

The tripod structure, measuring 330 ft on its equilateral sides, will be supported by 200-ft tapering circular columns 30 ft in diam at the base. Each corner will have triangular shaped lower hull footings which approximate 100 ft on each side and 20 ft in height. The structure will be as tall as a 20-story building and, when completed, will weigh about 7500 tons. The design will provide 30,000 sq ft of working area and air-conditioned quarters to accommodate 50 persons. Crew quarters will be topped by a helicopter landing deck. Rig power will be diesel-electric.

Rig 54 was not committed to any operator or groups at the time the announcement was made. Completion date will be about April of 1962.

Trucking Rates Go Up August 15

Oilfield trucking rates are scheduled to go up after August 15th according to Interstate Commerce Commission order in Docket MC-C-1891, issued June 14th. The schedule below is not nearly as high as requested by the Oil Field Haulers Association in ten midwestern and southwestern states. The previous minimum, according to Scale B, was 46 cents per 100-lb for a 100-mile haul. The OFHA sought an increase to 56 cents per 100 lb for the same distance. The ICC approved minimum rate (Scale A) in effect after August 15 is 47 cents per 100 lb for a 100-mile haul.

Cents Per 100 Pounds

Miles	Previous Minimum (Scale B)	Approved Minimum (Scale A)	Rates Requested By Haulers
10	15	16	23
20	20	21	26
50	30	31	38
80	42	43	50
100	46	47	56
150	58	60	68
200	69	71	78
300	88	91	98

In Texas, the Oil Field Haulers Association has withdrawn its request to the Texas Railroad Commission for higher tariffs in the Lone Star State.

Contractor Personnel Training Program

The AAODC, AOSC (Association of Oilwell Servicing Contractors), and the API will cooperate with the Petroleum Extension Service of The University of Texas to provide supervisory training courses in well servicing. George Walters of Great Western Drilling Co. at Midland, Texas, heads the AAODC cooperating committee. Tom Goebel of Spur Well Service, Houston, will represent the AOSC in the program.

Drilling Activity Comes Back

For the first time in 1961, total active rigs in the U. S. and Canada, according to weekly Hughes Tool Reports to the AAODC, reached levels of last year. U. S. rig count hovered at the 1800 mark, while Western Canada accounted for the biggest increase. Rig activity there jumped from a low of 79 rigs on May 8 up to 168 rigs at the end of June . . . a 53% increase in one month. Highest rig count this year was reported June 5 when U. S. and Canadian totals reached 1967 active rigs.

20,000 PSI Controlled by W-K-M Balanced Stem Valves

The cutaway illustration below illustrates how W-K-M Balanced Stem Valve gives positive finger-tip control of high pressures. The balancing stem at the bottom balances out the direct stem thrust inherent in most valves, resulting in the easiest possible operation. No other high pressure valve provides such positive control over seating pressure.

W-K-M Balanced Stem Gate Valve
1-11/16" — 2-9/16"
10,000; 15,000; 20,000 psi W.P.
W-K-M Single Balanced Stem Valve
Dual Balanced Stem Valve
Composite Balanced Stem Valve
Write for Catalog 200
P. O. Box 2117, Houston 1, Texas

W-K-M DIVISION
ACF INDUSTRIES

by
no other
method,
short of
a costly
completion,
can you be
sure of the
commercial
value of a
formation.

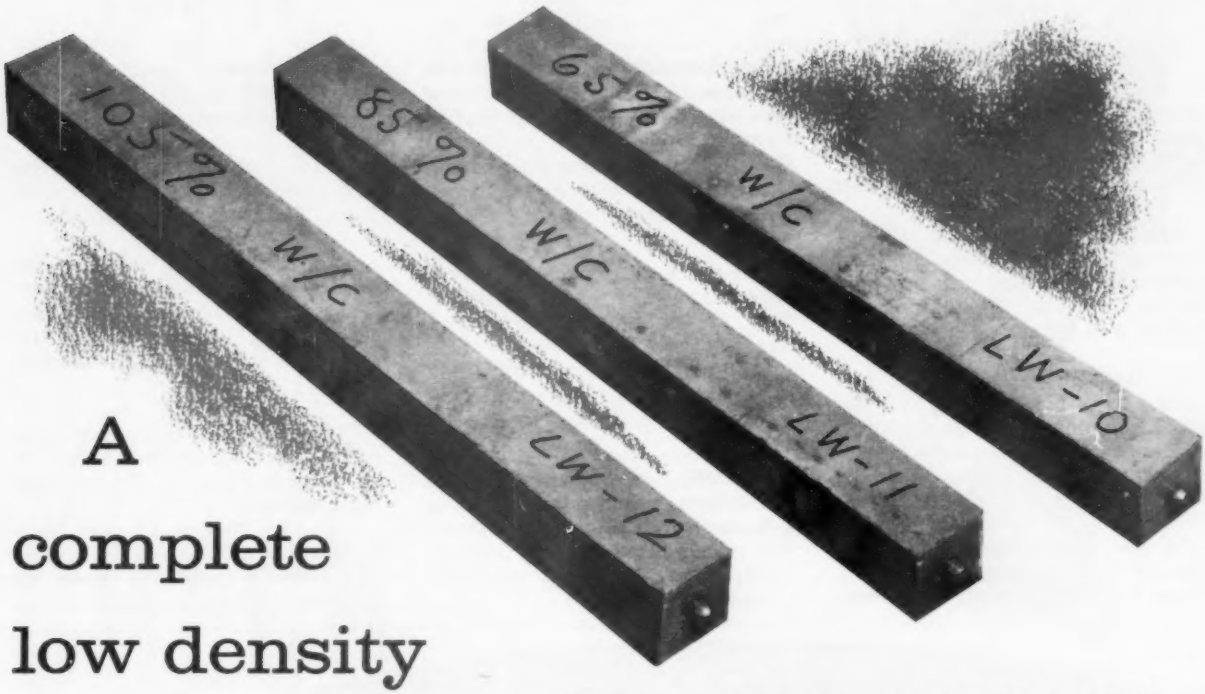
A WORLD OF EXPERIENCE

JOHNSTON TESTERS

DST to be sure!

HOUSTON, TEXAS
CALGARY, CANADA

Trinity LITE-WATE



A complete low density cement that is

SULPHATE RESISTANT

Shown above are three unretouched photos of test bars produced from TRINITY LITE-WATE neat slurry that were immersed in a 5% sodium sulfate–5% sodium chloride solution for a period of more than one year. These bars are completely sound and show no expansion.

In the range of lightweight cement slurries, TRINITY LITE-WATE produces a slurry which is:

1. Sulfate resistant for lasting casing protection.
2. Remains impervious to migrating fluids.
3. Light enough to circulate.
4. Strong enough for any casing seat.
5. Strong enough to permit hydraulic fracturing.
6. Easy to mix, easy to pump.

For TRINITY LITE-WATE cement call your service company.

For complete Laboratory Data call your local Trinity Representative or write Dallas Office, P. O. Box 2698 or phone RIverside 2-8111.

75 lb. Dry Volume per cubic foot

TRINITY

PORTLAND CEMENT DIVISION

GENERAL PORTLAND CEMENT COMPANY

DALLAS·FT.WORTH·HOUSTON

Suppliers' Parade

The Youngstown Sheet and Tube Co. has established a steel service center sales division and named as its manager, Jennings R. Lambeth, formerly vice president, sales, Jones & Laughlin Steel Warehouse Div.

Sales and service of Sargent Engineering Corp. downhole pumps and production items are now provided in the Cut Bank, Mont., area by Taylor Well Service.

Piping Engineering Co. has opened a new plant in Sand Springs, Okla. Equipment includes a 400-ton hydraulic ram pipe bender and automatic pipe coiling machine for pipe through 6⅝-in. OD.

Magnet Cove Barium Corp. has formed a new Magcobar Texas Gulf Coast marketing region by consolidating personnel, equipment and facilities of the Houston sales and service organization and Kaffie Lumber & Bulk Barites, Inc., of Corpus Christi. Temporary headquarters are at 1319 Agnes Street, Corpus Christi.

Iverson Supply Co. has moved headquarters from Tulsa, Okla., to 910 Fidelity Union Tower, Dallas, Tex. A sales office under the direction of M. C. Niblack, vice president, sales, has been established at 1011 Mayo Building, Tulsa.

The 1961 Road Show of Ideco, one of the Dresser Industries, is now on a 5-month tour of major oil areas. The mobile display includes oilfield drilling, servicing and workover equipment.

New Canadian agent for Gray Tool Co. is G. G. Oil Field Service Co., Ltd., Edmonton, Alta.

Go, Inc., has acquired the facilities of Go Oil Well Services, Inc., in Tyler, Tex., and Shreveport, La.

Flow Equipment Co. has appointed Continental-Emsco authorized export distributor of Floco positive displacement meters and other oilfield products it manufactures.

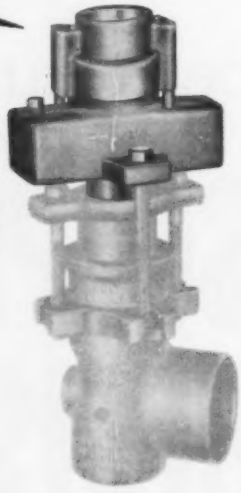
Continental-Emsco Co. has opened a new supply store in Indianola, Neb., and named J. B. Anderson store manager.

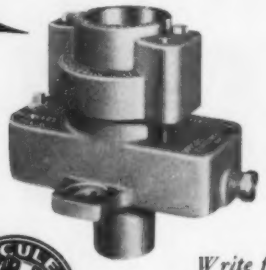
AiResearch Industrial Division of The Garrett Corp. has appointed Southwest Industries, Inc., distribu-

YOU CAN ELIMINATE BURNED PACKING FOR LESS THAN $20.00

HERCULES OIL RESERVOIR UPPER GLAND

Fits all Hercules Stuffing Boxes and costs only $18.75 to $19.75, complete.





The Hercules Oil Reservoir Upper Gland fits all Hercules Duplex Stuffing Boxes and was designed primarily for use on "problem" wells which pump-off and burn the stuffing box packing. The reservoir capacity is 1 fluid quart. The polished rod moves through the oil in the reservoir which lubricates and cools it. The oil film on the polished rod is controlled on the "up stroke" by the Split Cone Packing Ring (located between the Oil Reservoir Gland Body and the Cap). Excess oil and the dust or sand which invariably collect on the polished rod are wiped off by the Split Cone Packing Ring on the "down stroke." This excess oil and dirt are channeled back into the reservoir by means of the specially-designed Cap. The dirt will settle in the reservoir and can be removed through the drain plug.

Write for Complete Information

HERCULES TOOL COMPANY

MANUFACTURERS OF OILFIELD EQUIPMENT

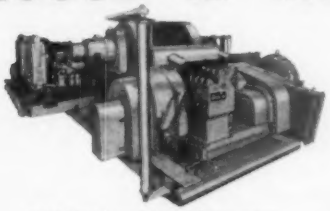
GENERAL OFFICES AND PLANT • TULSA, OKLAHOMA

Export Representative: Oil Field Equipment Co., Inc. 90 West Street New York, N. Y.

Don't fight it...

CHECK

WILSON SUPER MOGUL "42" RIG



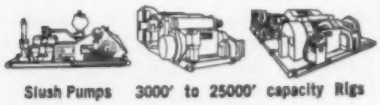
• Priced well below any comparable competitive rig

Wilson

WILSON MFG. CO., INC.

Wichita Falls, Texas • The Home of RED IRON

Winchmobiles Traveling Blocks Speedwinches



Slush Pumps 3000' to 25000' capacity Rigs

tor for AiResearch turbochargers in Texas, New Mexico, Colorado, Nebraska, Kansas, Oklahoma, Louisiana, Mississippi, Alabama, Arkansas, Missouri and Illinois.

Clark Bros. Co., one of the Dresser Industries, has added Mitsubishi Zosen, Tokyo, Japan, to its overseas network of licensed manufacturers. Sale of Japanese-built Clark compressors will be handled through Nippon Clark, a Japanese trading company to be jointly owned by Dresser A.G. and Mitsubishi Zosen.

Armadillo Plastics, Inc., has moved into a new plant and office building at 8207 Millet, Houston, Tex.

Newest Atlas Bradford Co. supply store is in Ozona, Tex. Bill Myers is store manager, and T. H. Wellman is area salesman.

The Chicago-based Artnell Co., headed by A. C. Allyn, has acquired control of the Eastman Oil Well Survey Co. Eastman's headquarters will remain in Denver, Colo., and Philip D. Arterburn will remain president.

The Midland, Texas, sales and service offices and parts warehouse of Clark Bros. Co., division of Dresser Industries, Inc., are now in new quarters at 1501 West Industrial Blvd.

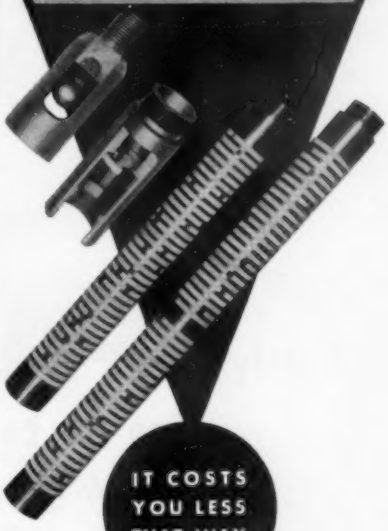
Welex has opened the first wireline service station at Poteau, Okla., in the Arkoma Basin. In charge is R. L. Smith, logging operator, formerly in the firm's Liberal, Kan., district. The firm also has opened new stations at Woodland, Calif., and Albion, Mich., as well as a sales office in Kilgore, Texas.

The Dowell Div. of The Dow Chemical Co., has opened a new oil well cementing station in Houma, La., under the management of Russell Norwood. A new, heavy-duty cementing unit with two independent pumps and a mechanical mixer for uniform slurry is currently in service there. This equipment will be available also at other Dowell cementing stations now under construction.

Visco Products Co. has formed two new sales and service districts — one covering the Four Corners area, with F. L. Stark as manager in Farmington, N. M.; and the other in the Cushing, Okla., area, with R. C. Newman as manager in Cushing.

Let R-u-b-b-e-r Take The Wear

in your sucker rod pumps



IT COSTS YOU LESS THAT WAY

• MARTIN RUBBER & DUCK RINGS give excellent life in dirty abrasive fluids . . . high or low gravity . . . much or little water . . . shallow or deep wells. They last for years in the easier pumping wells. Replacement rings cost comparatively little.

• MARTIN PLUNGER BODIES, precision grooved, drilled and threaded (no underneath fluid passage), usually last for years. Tube or barrel costs are often cut in half.

• The replaceable SYNTHETIC RUBBER GUIDES in MARTIN CAGES last longer than any metal, and the cushioning of the ball increases your ball & seat life. Results are often truly amazing. (Patent No. 2,591,174)

Write for our new catalog or see it in the Composite (24th Edition). All products sold thru supply companies.

JOHN N. MARTIN

Manufacturer

9 W. BRADY STREET • TULSA, OKLAHOMA

Appointments and Promotions

Bovaird Supply Co. — Gentry Adams, store manager at Great Bend, Kans.; R. E. Batchelor, Jr., store manager at Liberal, Kans.; and W. F. McIlvain, store manager at Farmington, N. M.

Harold Brown Co. — Pat Childs, vice president, sales, formerly sales manager.

Cameron Iron Works, Inc. — G. S. Leonard, manufacturing manager of the pressure control equipment division, formerly works manager of the Houston, Tex., plant of National Supply Co.

Edward Valves, Inc. — Robert C. Hicks, sales engineer in southeastern New Mexico and West Texas, including the Panhandle.

Hughes Tool Co. — Arthur H. Wooler, vice president, manufacturing, succeeding Harry E. Rogers who has retired; Emil E. Pagel and Gerald F. Bevill, director and assistant director of purchases, respectively; and Gayle Whiddon, national representative, sales, Houston.

Charles Wheatley Co. — David R. Davis, coordinator of sales, advertising and pricing, formerly sales engineer for The Lunkenheimer Co., Pacific Valves, Inc., Hancock Div., Manning, Maxwell & Moore, and Grove Valve and Regulator Co.

Worthington Corp. — Bob D. Keeth, distribution representative for the firm's construction equipment sales organization.

Jones & Laughlin Supply Div. — S. A. Windham, salesman, Shreveport, La.; and K. E. Manford, B. T. Collins, W. F. Rice and R. L. Mikulec, store managers at Corpus Christi, Tex., Laurel, Miss., Pleasanton, Tex., and Victoria, Tex., respectively.

National Supply Div., Armco Steel Corp. — Charles M. Struffolino, field engineer, Columbus, Ohio.

Armour Industrial Chemical Co. —H. S. Lawton, marketing director, formerly commercial development director.

BJ Service, Inc. — three new assistants to the sales manager: Henry A. (Red) Coleman, Abilene, Tex., division office; Jim B. Gardner, Corpus Christi, Tex., sales office; and Herbert A. Bergman, New Orleans, La., sales office.

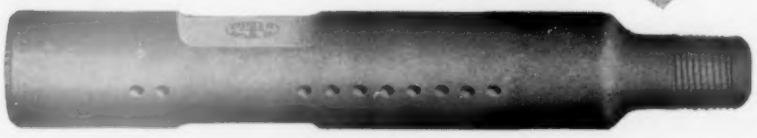
Black, Sivalls & Bryson, Inc. — Charles L. Rhodes, branch manager, Hobbs, N. M., formerly sales engineer in the Midland-Odessa area of Texas.

Orbit Valve Co. — new sales representatives: W. S. "Bill" Peatross, southeast Texas and southwest Louisiana, with headquarters in Beaumont, Tex.; S. E. "Woody" Yandle, southeast Louisiana from New Orleans; and C. W. "Bill" Knott, south Texas, with headquarters in Corpus Christi.

Rector Well Equipment Co. — E. C. Kopp, sales and service representative, formerly vice president and division manager of Maloney Crawford Tank Co.; and Welton R. Baxter, field and sales representative, formerly service engineer for Dowell, Inc., Mud Control Labs and Advanced Oil Tools.

Reed Roller Bit Co. — C. J. Fontaine, domestic sales manager, formerly divisional manager of Central American sales; and B. A. (Beau) Wendt, assistant to the vice

Only SPANG can give you the best in Strength, Service, Economy and Footage in a Prosser-type SWIVEL ROPE SOCKET



There are times when an ordinary rope socket will meet your needs. But there are too many times when you can't afford to risk trouble—when you require a rope socket that's precision made and utterly dependable under all conditions. This is the time you'll be glad to have a Spang Rope Socket on the business end of your string—

. . . AND HERE'S WHY SPANG'S BEST

■ Completely Heat-Treated for maximum toughness and hardness ■ Precision machined ■ High steel strength ■ Extra strong joint ■ Carefully finished inside bore ■ Perfect setting for cable ■ Socket neck grooved for the use of fishing tools ■ Made by the country's oldest and largest manufacturer of cable tools

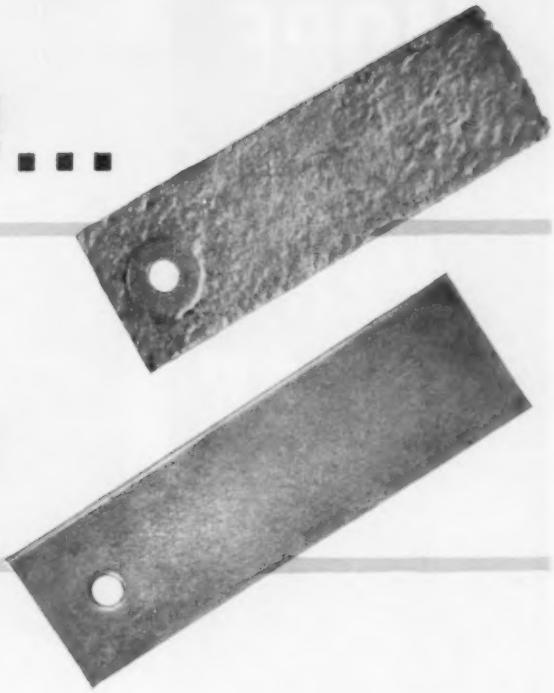
FIRST CHOICE OF DRILLERS EVERYWHERE

SPANG & COMPANY

DEPT. O-7 BUTLER, PENNSYLVANIA

For over 60 years Manufacturers of Spang Weldless Jars and a Complete Line of Cable System Drilling and Fishing Tools for Oil and Gas Wells, Water Wells, Prospect Drilling and Shot Blast Holes.

before...



...and after

with *Visco* corrosion control!

HERE are several sets of typical before and after coupon test figures in wells now getting Visco Anti-Corrosion Treatment. Estimate the *tons* of well equipment metal saved by Visco Treatment, and you get an idea of the *dollars* saved in labor and replacement costs . . .

Well	Maximum Weight Loss—Mils/year	
	Before Visco	With Visco
1.	11.00*	0.02
2.	4.90	0.40
3.	8.10*	0.86
4.	7.50	0.08
5.	16.00*	1.30

** These wells receiving "anti-corrosion" treatment. Replaced by Visco.*

1 mil=.001 inch. A corrosion rate of 216 mils per year means that the corrosive attack, if uniform, would have corroded away the entire surface of the metal to a depth of .216 inches in a year. However, the real danger of high corrosion rates, as the coupon shows, is the much deeper and faster penetration occurring at localized areas.

These are not super-success figures. Chances are high that Visco can equal or better these results in *your* wells. Phone, Sugar Land, DImond 9-3141, or write for positive Visco action today.

VISCO PRODUCTS COMPANY

A Subsidiary of Nalco Chemical Company

P.O. Box 87 • Sugar Land, Texas

Visco® ... CONSISTENTLY EFFICIENT OIL FIELD CHEMICALS

MORE HOLE PER DOLLAR

THE GEODRIL MODEL G COMPACT AUTOMATIC DRILLING CONTROL GIVES YOU:

- Longer Bit Life
- Better Coring and Reaming
- Straighter Hole
- Reduction in Twist-Offs

SAVES YOU:

- Costly Downtime
- Equipment Wear
- Time to Contract Depth
- Dollars per Day

Considerable savings to the contractor in both time and money can be obtained through any of these.

Today's highly competitive drilling situation makes it essential that the optimum drilling rate be maintained from grass roots to total depth. The Model G Geodril Automatic Driller provides this assurance while maintaining safe, reliable control of the brake at all times.

If you want more hole per dollar, contact your nearby Geograph Oil Field Services Office. Ask for Catalog 223.

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OIL FIELD SERVICES
P. O. Box 1276
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A royal inspection of the new barite processing and drilling mud plant built by Sherkat Sahami Magcobar Iran was attended by: (left to right) S. S. Hanley, managing director of Dresser, A.G.; J. B. O'Connor, president of Dresser Industries, the parent organization which planned the Iranian facility; and His Imperial Majesty, the Shah Mohammed Reza Pahlevi of Iran. It is expected that the new Magcobar facility will employ about 250 men and will save about $2,000,000 a year in foreign exchange for the Iranian economy.

president of sales, formerly Texas Gulf Coast division sales manager.

Schlumberger Well Surveying Corp. – J. R. Peasley, northeast division manager in Evansville, Ind.; and J. T. (Johnny) Foster, succeeding Peasley as sales manager for the Oklahoma division.

Smith Industries International, Inc. – Kenneth H. Swart, executive vice president and general manager, formerly president of Smith Tool Co.; Arthur S. Marshall, vice president, sales; Manuel L. McAlister, vice president, manufacturing; Robert F. Evans, vice president, engineering; and H. M. Nelly, Jr., vice president, and Harry E. Kidder, director, of industrial relations.

Oil Well Supply Div., U. S. Steel Corp. — James A. Durham, store manager, Clarksburg, W. Va.; Harold J. Bourgeois, store manager, Eunice, La.; and John J. Boslet, sales representative, store area, Beatyville, Ky.

Waukesha Motor Co. — F. C. Schulze, vice president of sales, formerly general sales manager.

Welex — Jerry Cahill, formerly in charge of the Tyler, Tex., station, now in charge of both the Tyler and Shreveport, La., districts; P. R. Lam, from shooter to sales engineer in charge at Tyler; B. F. Chambless, from sales engineer to assistant district manager in charge at Shreveport; Louis Wood, division sales engineer as head of the recently-opened Kilgore, Tex., office; G. F. Carroll from shooter to sales engineer at Stillwater, Okla.; and D. E. Sullivan, sales engineer in charge of the El Dorado, Kan., district.

SECONDARY RECOVERY

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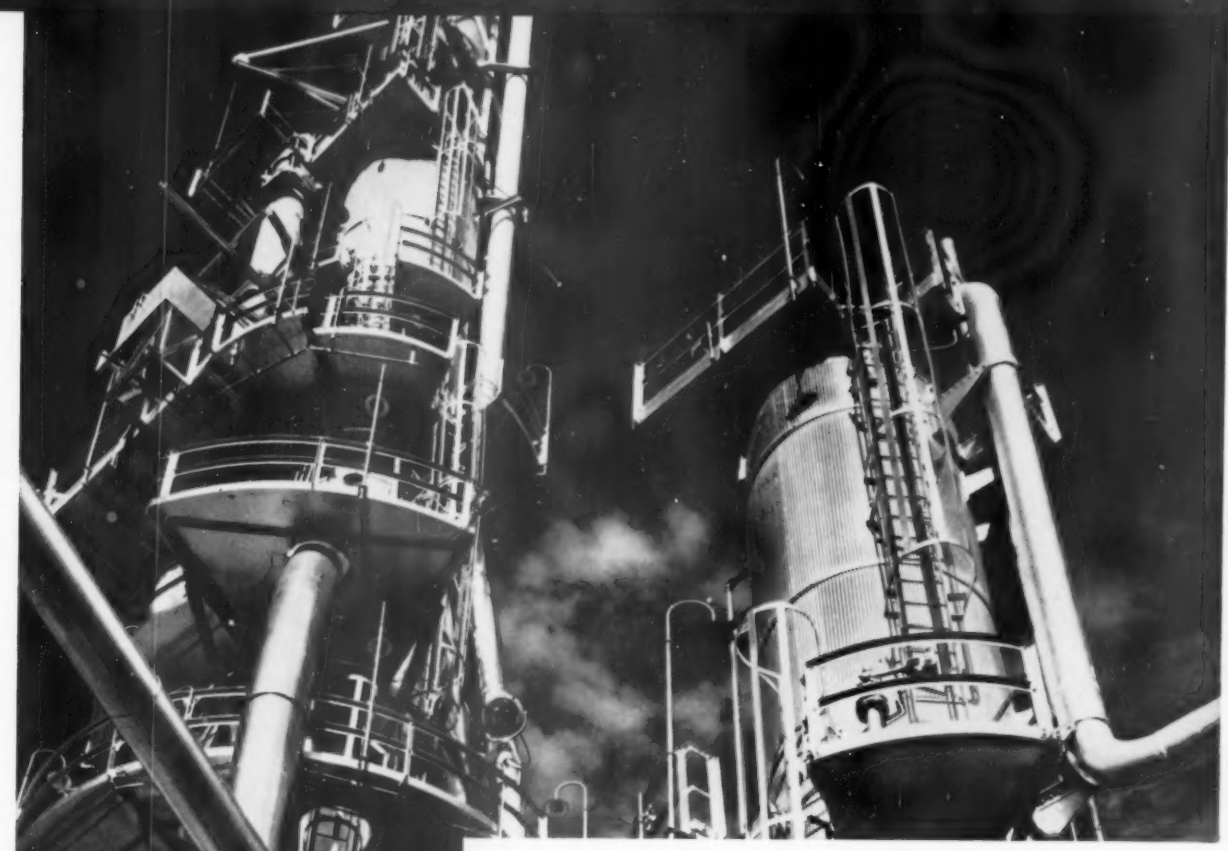

Refractory insulating concrete linings keep cats cracking

Refractory insulating concrete, bonded with LUMNITE calcium-aluminate cement, is being used more and more to line regenerators, cyclones, strippers, catalysts and reactor transfer lines of fluid catalytic cracking units. On stream in FCCs across the country, these industrial concrete linings will resist severe erosion and abrasion caused by catalyst fines ... resist attack by acid condensate ... and provide insulation at high temperatures.

Installation of monolithic concrete linings is fast, easy, economical – whether cast in place, gunited or plastered. Concrete reaches service strength in 24 hours.

For added convenience, castables bonded with LUMNITE cement are available from leading manufacturers of refractories. These are packaged mixtures, ready for use with just the addition of water. For more information, write Universal Atlas Cement, 100 Park Avenue, New York 17, N. Y.

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Universal Atlas Cement
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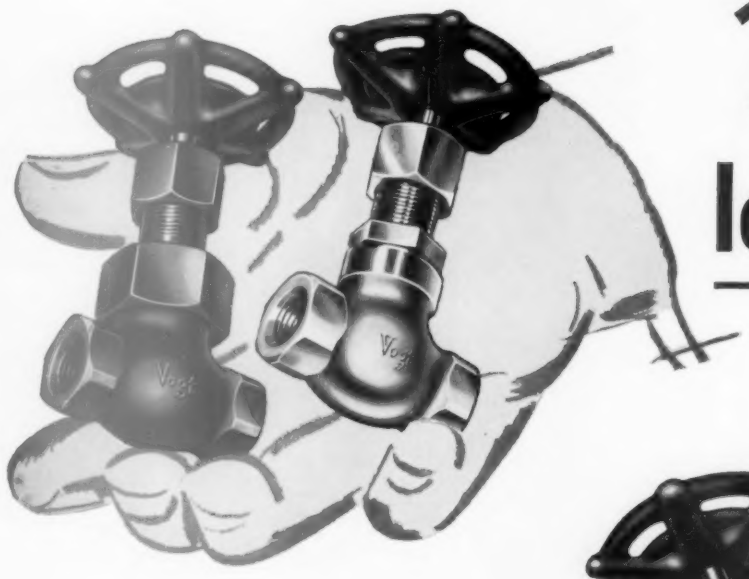
New lower price



Enlarged production facilities combined with improved manufacturing techniques enable Vogt to pass on the effected savings to our customers.

Service proved — these valves have always been a standard of quality for meter and gauge line service. You no longer need to compromise for less because of price! Send for Folder GP-9 giving specifications and engineering data on both globe and angle types, forged from stainless or carbon steel for every meter and gauge line service.

Address Dept. 24A-FPC

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Louisville, Kentucky
SALES OFFICES: Camden, N. J., Charleston, W.Va., Chicago, Cleveland, Dallas, Los Angeles, New York, St. Louis.

Construction Briefs

Tenneco Chemical Co., subsidiary of Tennessee Gas Transmission Co., has awarded contracts for a substantial part of its new petrochemical complex on the Houston Ship Channel.

M. W. Kellogg Co., New York will build a 100,000,000-lb-per-year, $12,000,000 acetylene plant to use a process developed by Societe Belge de L'Azote of Belgium.

Off-site construction in connection with the plant will be done by Bechtel Corp., San Francisco, under a separate $1,500,000 contract.

Hydrocarbon Research, Inc., New York, will erect a 730-ton-per-day, $6,500,000 plant on the Tenneco property to produce oxygen and high purity nitrogen for Tenneco and other industries in the area. Plant will be owned and operated by Hydrocarbon.

United Engineers and Constructors, Inc., Philadelphia, has $15,000,000 construction contract for Borden Chemical Co.'s methanol and vinyl acetate monomer plants at Geismar, La., part of the planned $50,000,000 Monochem, Inc., petrochemical complex.

Chemical Construction Corp., New York, will design and erect the hydrogen synthesis section of a new multi-million dollar liquid hydrogen plant near Fontana, Calif., being built by Linde Co., Div. of Union Carbide Corp.

Cyprus Mines Corp., Los Angeles, will build and operate a number of small plants costing approximately $500,000 each for the removal of liquid products from natural gas in areas not served by large absorption plants. First three plants will be in Texas, Oklahoma and Louisiana. Operations will be managed by Cyprus Oil Co. Div., Houston.

Badger Ltd., London, has been awarded the design-engineering-construction contract for a 35,000,000-lb-per-year phthalic anhydride plant at Hull, Yorkshire, to be built by Grange Chemicals, Ltd., and California Chemical Co. Adjacent to the Distiller Co., Ltd., chemical works, the new plant will produce phthalic from an orthoxylene feedstock using a process licensed by California Research Corp.

Kellogg International Corp., London, has contract to build Gulf Oil's first European refinery, a 30,000-bpd plant at Stigsnaes, South West Zealand, Denmark.

Scientific Design Co., Inc. New York, will design and engineer Sweden's first direct air oxidation ethylene oxide plant, a 33,000,000-lb-per-year installation to be built at Stenungsund for Mo och Domsjo Aktiebolag. The Swedish company will also build an ethylene glycol plant designed by SD.

A $36,400,000 refinery will be constructed between Salisbury and Umtali in Southern Rhodesia by American Independent Oil Co. Also planned are a nitrogenous fertilizer plant, a petrochemical industry and a pipeline from Beira, Mozambique. Total investment will be $84,000,000.

O. L. Olsen & Co., Houston, Tex., will construct the 12 MMcf per day absorption-refrigeration type gas processing plant near McGregor, N. D., to be operated by H. L. Hunt interests, Dallas, Tex.

Foster Wheeler Corp., New York, has design and construction contract for a 700-bpd propane deresining plant at the Quaker State Oil Refining Corp. refinery, St. Mary's, W. Va. Plant will cost approximately $600,000.

A new crude oil distillation unit with 70,000-bpd capacity will be constructed at American Oil's Sugar Creek, Mo., refinery. Process and basic engineering designs are being handled by the company's staffs at Whiting, Ind. Ralph M. Parsons Co., Los Angeles, has engineering-construction contract.

Industrial Quimica Products, Brazilian subsidiary of W. R. Grace & Co., will quadruple capacity of its plant at Ftalicos to make 240 tons a month of phthalic anhydride. Grace also will build a plant at Bogota, Colombia, with capacity of 60 tons a month.

Gewerkschaft Erdol-Raffinerie Emsland will expand capacity of their Lingen, Germany, refinery from 2,500,000 to 3,000,000 tons a year.

Saudi Arabian Refining Co., established by a member of the royal family, has concession to build a 20,000-bpd refinery at Jeddah.

Burapha Setthakit Co. (Eastern Economic Development Co.) proposes to construct a second 5000-bpd refinery in Thailand.

Canadian Superior Oil of California, Ltd., Calgary, will build a $4,300,000 gas recovery plant in the Harmattan-Elkton field near Red Deer, Alta.

A $41,000,000 chemical industries complex at Balashi, Aruba, will include an ammonia plant financed and operated by Standard Oil Co. (New Jersey) and nitric acid, urea and fertilizer plants financed and operated by Aruba Chemical Industries NV.

Hudson Engineering Corp., Houston, will design and build a $5,500,000 natural gas processing plant at Catu, Bahia, Brazil, for Petrobras, Rio de Janeiro.

Wyandotte Chemicals Co. plans construction of a $3,500,000 propylene oxide plant on the Lower Detroit River at Wyandotte, Mich.

Kaighin-Hughes-Litwin, Inc., Toledo, Ohio, will build a 1425-bpd hydrofluoric acid alkylation unit at Pure Oil Co.'s Heath refinery near Newark, Ohio.

SATISFY MORE CUSTOMERS AT NO EXTRA

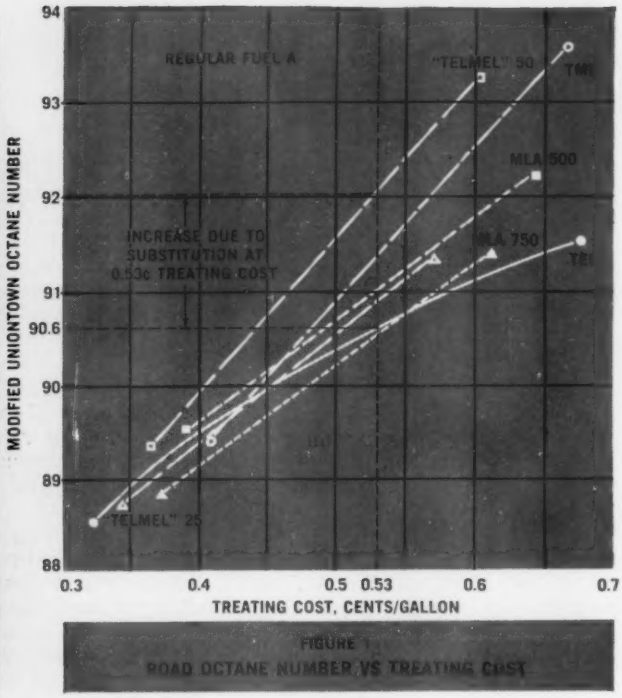

FIGURE 1
ROAD OCTANE NUMBER VS TREATING COST

NEW STRIDES IN antiknock research have made more types of lead alkyls available today than ever before. Now, by using the *right amount* of the *right additive*, you have the means to market a better performing gasoline . . . at no increase in cost. But tailoring an antiknock to a particular fuel can be a complex task—a vital problem Ethyl helps refiners solve every day.

Recently, Ethyl presented a paper at WPRA which gave typical refining antiknock selection cases. Take just one of these examples, which shows how important antiknock volatility can be in certain regular grade gasolines.

The Critical Portion

Of all the cars manufactured between 1958 and 1961 that were designed to run on regular gasoline, 38% came equipped with manual transmissions. This "stick-shift" segment, produced in the past four years, represents the most critical share of America's regular-fueled car population. Because of their engine characteristics, and depending on the fuel's composition, these cars should perform well on gasolines that contain lighter lead alkyls.

In figure 1 above, regular gasoline "A" is such a fuel—a blend of light straight-run and

The reduction in price of antiknock compounds, announced after this advertisement had been prepared, alters to some extent the comparative values shown. The price reduction also emphasizes the potential profits that result from taking a new look at the position of lead in optimum economic refinery operation.

ETHYL
ANTIKNOCK COMPOUND
ETHYL CORPORATION

COST THROUGH ANTIKNOCK SELECTION

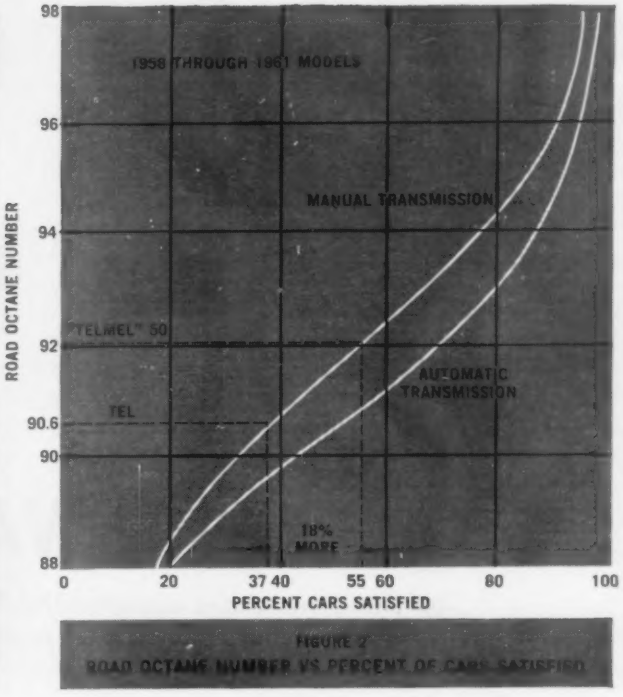

FIGURE 2
ROAD OCTANE NUMBER VS PERCENT OF CARS SATISFIED

reformate. Samples were treated experimentally with TEL, TML, mixed lead alkyls, and physical mixtures of TEL and TML. At the optimum antiknock treating cost of 0.53¢ per gallon (based on balancing reforming severity and TEL use), either 2.3 grams of "TELMEL" 50 mix or 2.65 grams of TEL met the lab specifications for the fuel. The selection therefore would be based on which antiknock provided superior road performance.

More Cars Satisfied

Figure 2 shows that the 90.6 road rating provided by TEL would satisfy only 37% of the manual transmission cars. With "TELMEL" 50, the resulting road rating of 92.0 would satisfy 55% of these cars—a gain of 18% more cars satisfied at the same treating cost.

This is only one of the antiknock selection situations facing the refiner—and only one of the rewarding opportunities open to him. It's typical of the problems Ethyl is well equipped to help *you* with. If you want assistance in selecting the most efficient antiknock for *your* refining requirements, call your Ethyl representative. He will also be glad to furnish you a copy of the WPRA paper referred to above.

Ethyl Corporation

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HELPFUL WATER CONDITIONING DATA FROM BETZ

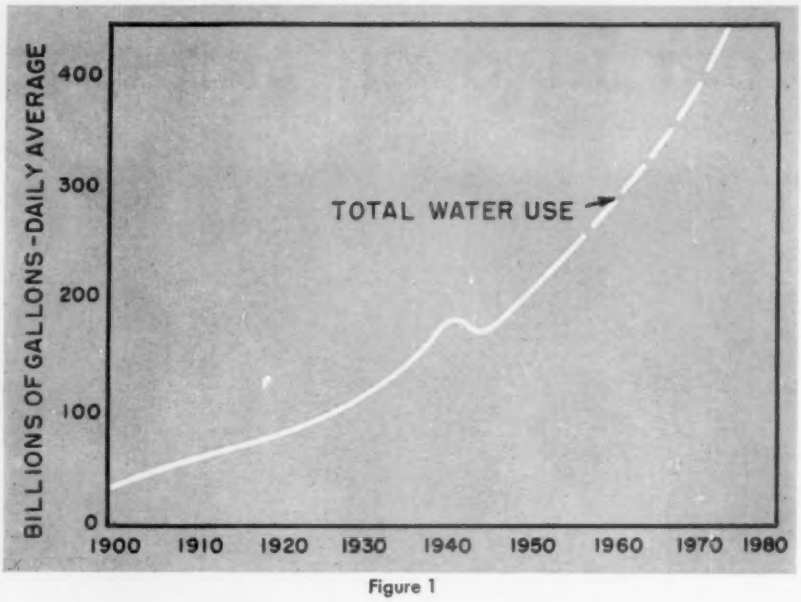

Figure 1

WASTING WATER IN YOUR

There are ample opportunities for the conservation of water in most industrial plants

WATER IS ONE of our most vital resources. Considerable concern has been expressed from time to time over the adequacy of our water resources. This concern is justified because of the enormous current water usage and the rate of increased usage predicted for the future as shown by Figure 1. The current water usage by industry alone is estimated as 70 billion gallons per day. It is anticipated that daily usage will soar to 115 billion gallons by 1975. Water requirements for various industries are typified by the data presented in Figure 2. With an expanding population and industrial growth it is important that serious attention by industry be given to the conservation and reuse of our water resources.

Industrial plants that are located in drought areas have been forced to cope with a water shortage problem much sooner than anticipated. In some of these cases, sewage plant effluent has been used for makeup to boilers and recirculating cooling water systems. The problems encountered in the treatment of sewage plant effluent to make it suitable for these purposes is thoroughly covered by Betz Technical Paper No. 138, a copy of which is available on request.

Many industrial plants located in other areas where water supplies have been considered adequate and inexhaustible, have found it profitable to conduct surveys of their water usages. Often, surveys of this type uncover unnecessary water losses, inefficient operations and equipment obsolescences. The correction of these conditions has led to a saving not only in water, but of dollars as well. A recent survey conducted at a chemical processing plant dramatically illustrates what can be done.

TYPICAL WATER REQUIREMENTS

Industry	Gallons per Tons
PETROLEUM	35,000
STEEL	65,000
PAPER	70,000
RUBBER	30,000

Figure 2

Case History

A chemical processing plant, considering an expansion program, found that the water supplies might not prove adequate for the anticipated operating conditions. The normal source of well water was already being supplemented by the use of city water which was already in short supply. One of the three wells normally used had been abandoned because of evidence of salt water intrusion. A simplified flow sheet of water usage for the plant is illustrated by Figure 3.

The survey revealed that a large quantity of hot condensate was being dumped to waste because of frequent contamination from process evaporators which introduced foam producing materials into the condensate. When this condensate returned to the boilers, severe boiler water carryover occurred.

Trouble also occurred with the lime-soda softener. The supplemental use of city water along with the normal well water created such a wide variation in makeup water characteristics that it was impossible to maintain proper balances. These poor balances resulted in the need for frequent backwashing of the filters and the maintenance of an abnormally high blowdown rate on the boilers.

The recirculating cooling water system contained numerous bleed-off points for miscellaneous water usages which made it uneconomical

to treat the system for prevention of corrosion. The corrosion products that accumulated were interfering with heat transfer, requiring added water flow to maintain process temperatures.

Briefly, the corrective measures applied involved the application of an *antifoam to the process evaporators* which eliminated contamination of the condensate. As a safety measure, however, an alarm system was installed which also operates a valve to divert the condensate, if and when contamination occurs. The return of the hot condensate materially reduced makeup requirements to the boiler so that the available city water proved more than adequate to handle boiler makeup requirements for the proposed operating conditions. With the use of city water alone for makeup to the boilers, uniform softener balances have been maintained and the filter backwash and boiler blowdown have been reduced to normal requirements.

Savings in heat, water treatment and water requirements far exceed the cost of the process antifoam and the cost of the alarm system used to correct the problem.

In addition, a check of the numerous draw-off points from the cooling system revealed unnecessary waste of water through open-ended hoses used periodically for washing equipment and left running. Cooling water for bearings and compressors was not returned to the main cooling water system. Elimination of these water losses permitted the cooling system to cycle and decreased makeup requirements to the point where the two existing wells could satisfy the water demands. These savings in water, in turn permitted corrosion control treatment to be justified economically. A check of the third well which had been abandoned for evidence of salt water intrusion indicated that the salt content was within a range to permit its use in the cooling system if necessary. This well was connected for emergency use to the cooling system. The effectiveness of the cooling water corrosion control treatment has limited corrosion of the steel parts in the system to less than one mil per year. Design temperatures and normal pressure drops through the heat exchangers are now maintained.

PLANT ?

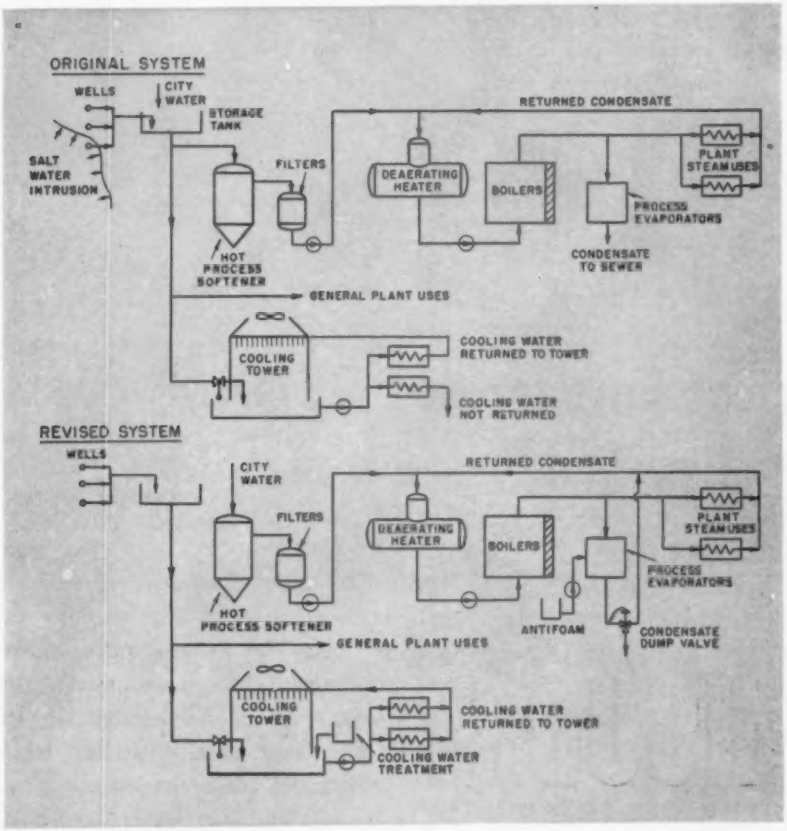

Figure 3

This survey and numerous others conducted by the Betz Consulting Division has revealed that there exist ample opportunities in many plants to bring about water conservation and oftentimes water re-use.

A survey of your plant water usages, treatment methods and water wastes may produce benefits both in water savings and dollar savings. Perhaps a process antifoam may be the answer. Talk it over with the Betz Engineer next time he visits your plant.

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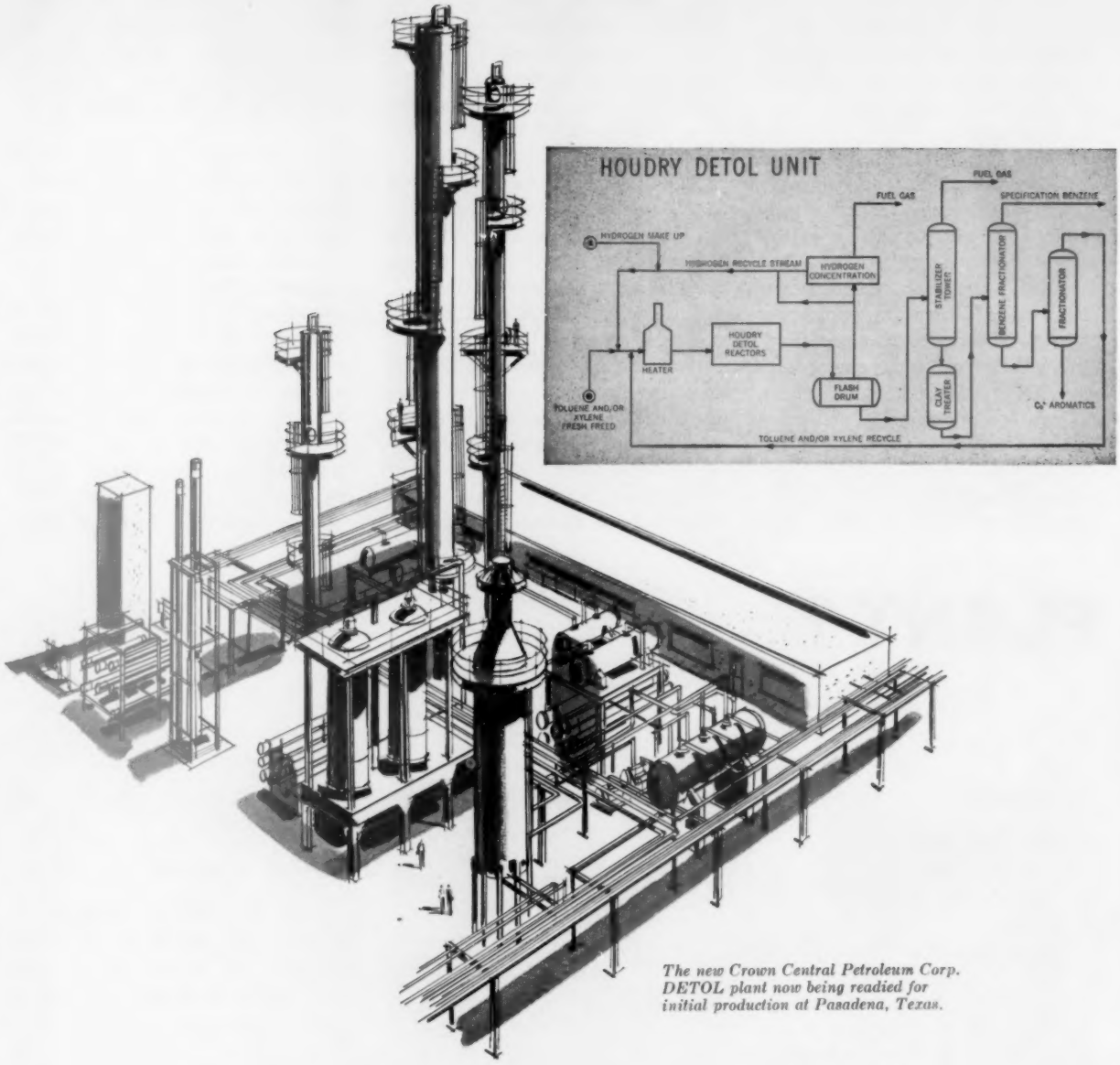
■ CONSULTANTS ON INDUSTRIAL WATER PROBLEMS



The new Crown Central Petroleum Corp. DETOL plant now being readied for initial production at Pasadena, Texas.

Crown Central Petroleum chooses DETOL Process for new 17-million gal/yr benzene plant

The Houdry DETOL Process for catalytic dealkylation of toluene and/or xylene will soon begin converting toluene feedstock to high purity benzene for Crown Central Petroleum Corp. in its new 17-million gal/yr plant in Pasadena, Texas.

DETOL offers benzene yield from the reactor of 96.5 mol percent of fresh toluene charge, high selectivity with minimum loss to undesirable by-products. Benzene product will meet acid wash and corrosion tests, will have freeze point of 5.4°C. or better. Non-aromatics and organic sulfur in feed are converted to light hydrocarbons and hydrogen sulfide. Catalyst is not affected by sulfur. Operating costs are estimated at 1.63 cents per gal. of charge, in the Gulf Coast area, including labor, supervision, maintenance, utilities, catalyst and chemicals. More information will be furnished on request.

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1528 Walnut Street, Philadelphia 2, Pa.
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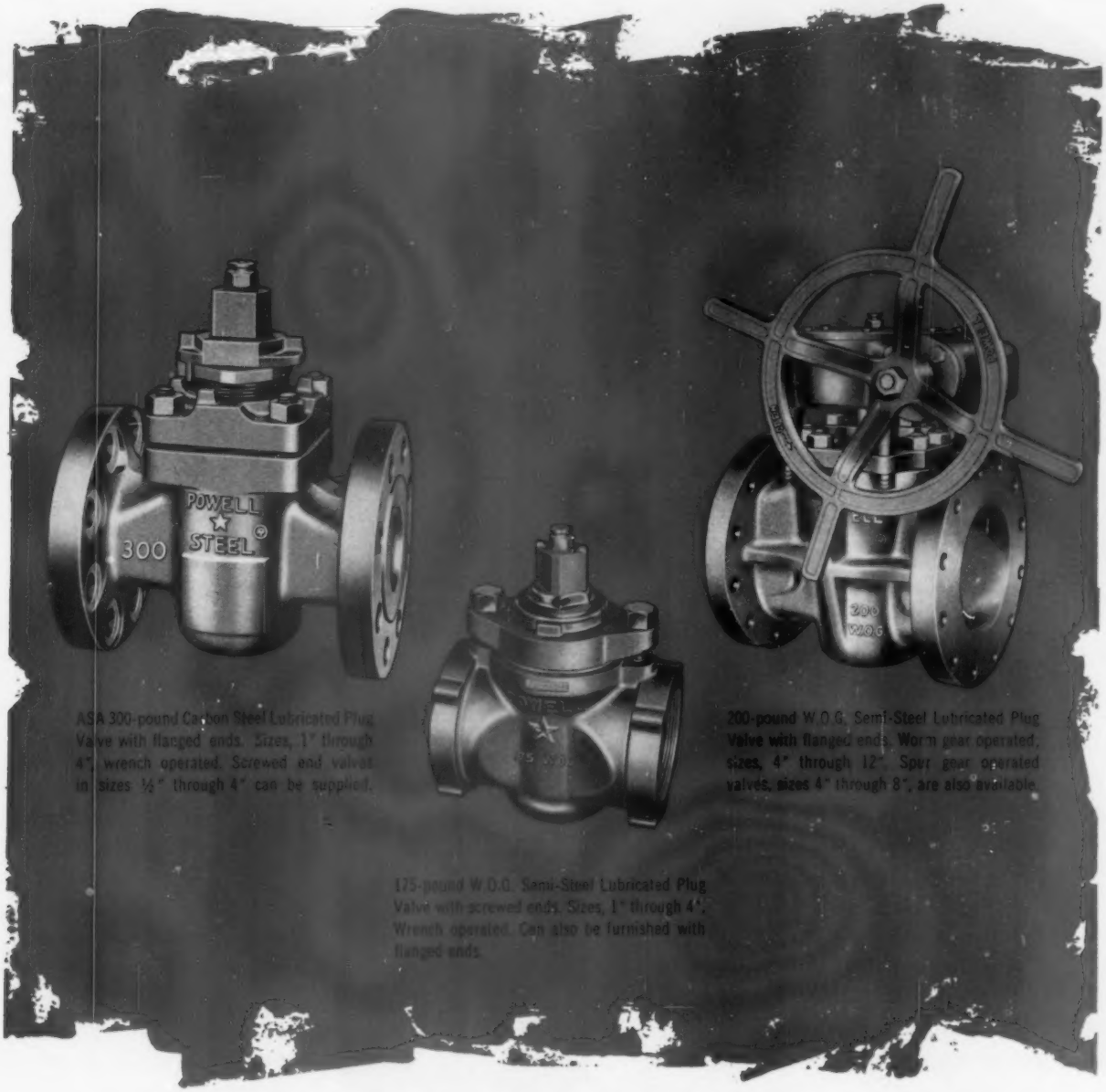
It is a matter of record, in refineries everywhere, that Powell valve performance really is paying off.

And equally important is the fact that whether you need valves to control the flow of water, oil, gas, air, steam or corrosive fluids—available in steel, bronze, iron or alloys—Powell has them.

You'll find every Powell valve is designed by engineers long experienced with the industry's valve requirements . . . and built by craftsmen who take pride making a valve you can count on.

So, by filling your flow control needs quickly, with truly reliable valves from one source of supply, you too, can be sure of valve performance that will pay off. For further information or assistance with special problems, contact your nearby Powell valve distributor or write The Wm. Powell Company, Cincinnati 22, Ohio.



ASA 300-pound Carbon Steel Lubricated Plug Valve with flanged ends. Sizes, 1" through 4", wrench operated. Screwed end valves in sizes ½" through 4" can be supplied.

175-pound W.O.G. Semi-Steel Lubricated Plug Valve with screwed ends. Sizes, 1" through 4". Wrench operated. Can also be furnished with flanged ends.

200-pound W.O.G. Semi-Steel Lubricated Plug Valve with flanged ends. Worm gear operated, sizes, 4" through 12". Spur gear operated valves, sizes 4" through 8", are also available.

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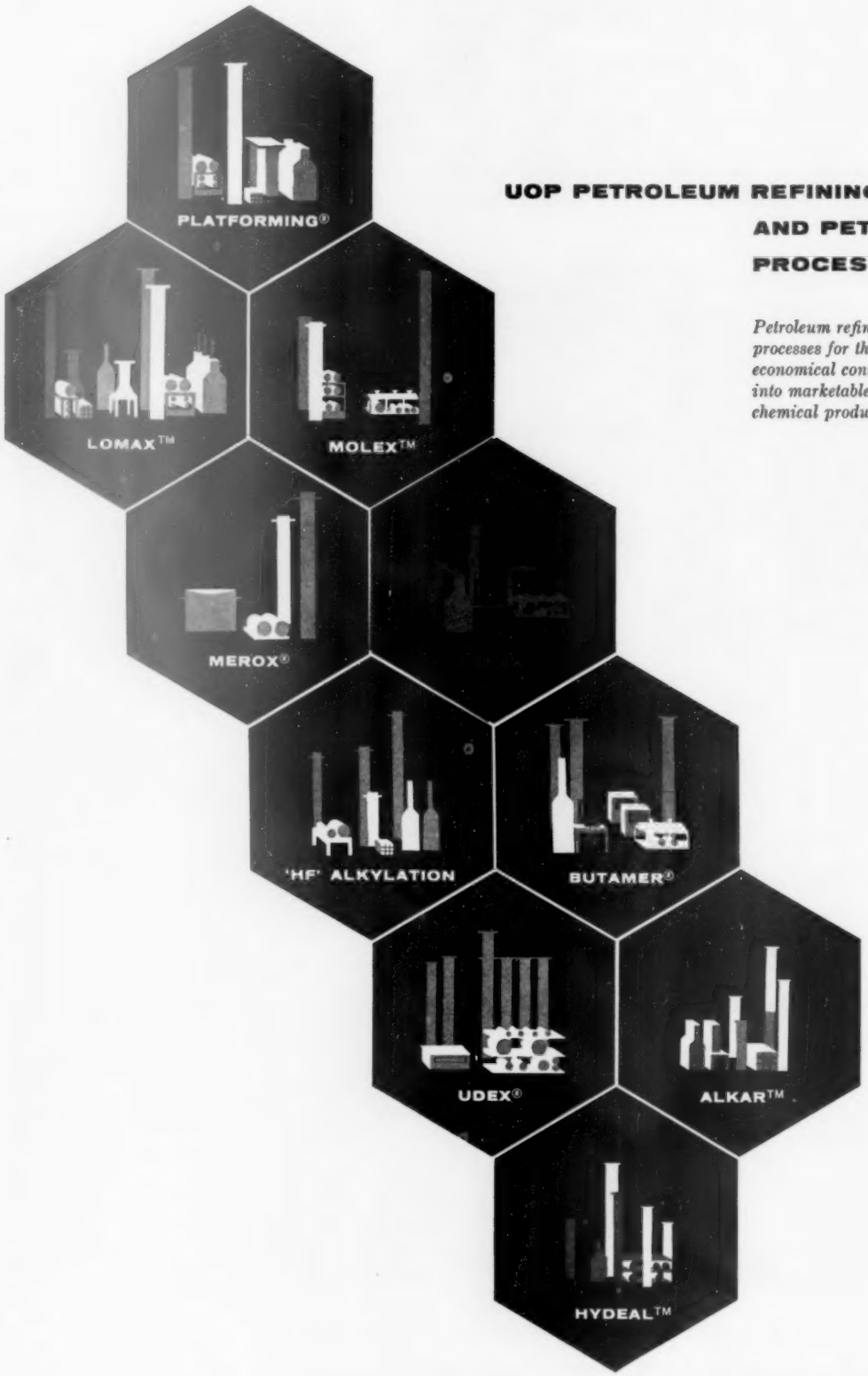
THE WM. POWELL COMPANY CINCINNATI 22, OHIO



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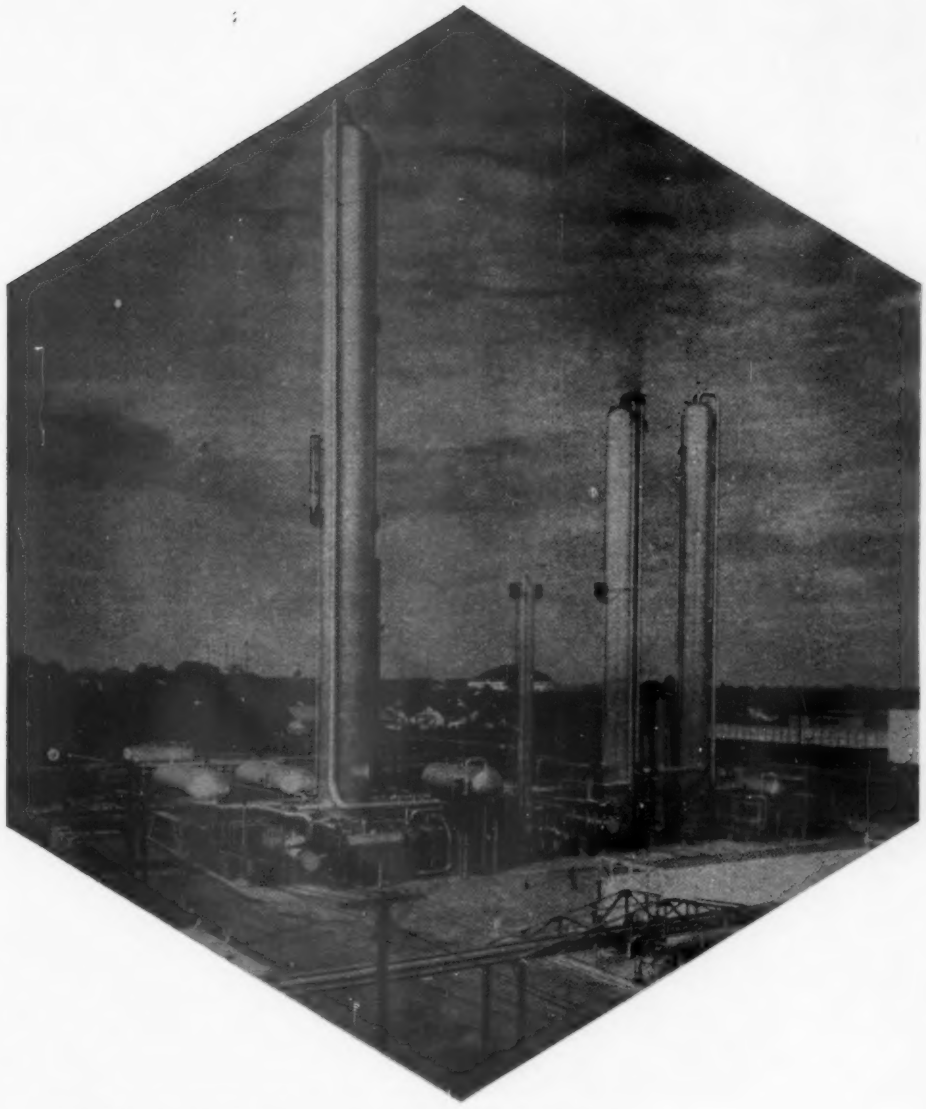
Petroleum refining and petrochemical processes for the efficient and economical conversion of petroleum into marketable fuel and chemical products.



now refiners can produce balanced blend gasoline with PENEX®

PENEX processing produces the highly-volatile iso-paraffinic blending fuels which have such excellent performance qualities, good sensitivity and warm-up characteristics, clean burning, and improved lead susceptibility. The best quality gasoline is a balanced blend containing these Penex produced iso-paraffins.

Penex is designed for the continuous catalytic isomerization of normal pentane, normal hexane and mixtures of both. Reaction conditions are extremely mild because of the nature of the reaction and the catalyst used. Conditions selected are such that regeneration is not required, thus reducing capital investment costs, simplifying operation and minimizing maintenance.

UOP offers a wide range of petroleum and petrochemical processes to refiners everywhere in the free world. A variety of technical services are also available from UOP to insure the profitable performance of these processes. Let UOP engineers evaluate your processing needs now.

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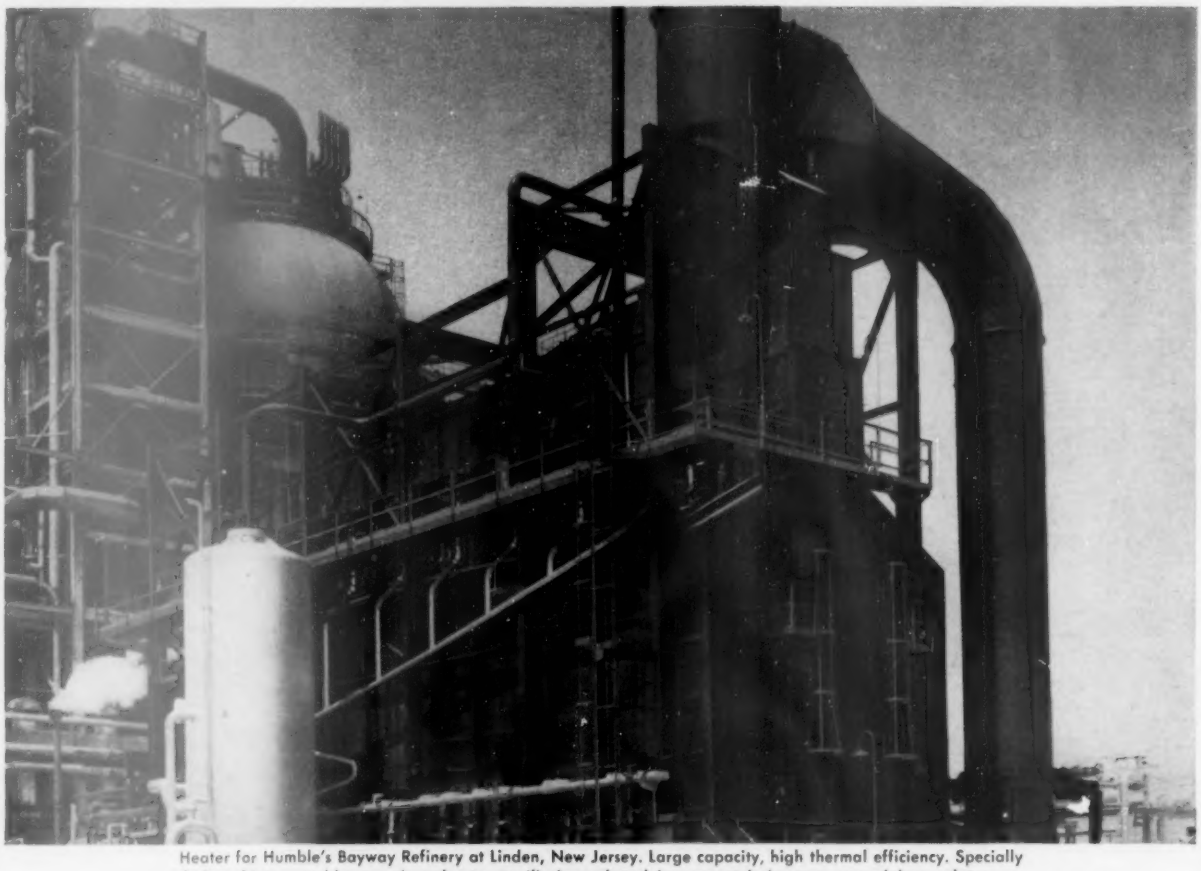
ENGINEERS AND CONSTRUCTORS FOR INDUSTRY



Heater for Humble's Bayway Refinery at Linden, New Jersey. Large capacity, high thermal efficiency. Specially designed integrated heater, air preheater, auxiliaries and stack in compact design to occupy minimum plot space.

Lummus Oil Heater for Humble's Bayway Refinery meets three tough design requirements

LARGE CAPACITY, HIGH EFFICIENCY, LONG RUNS

Humble Bayway knew exactly what they wanted in a replacement heater and turned confidently to Lummus to meet their difficult design requirements.

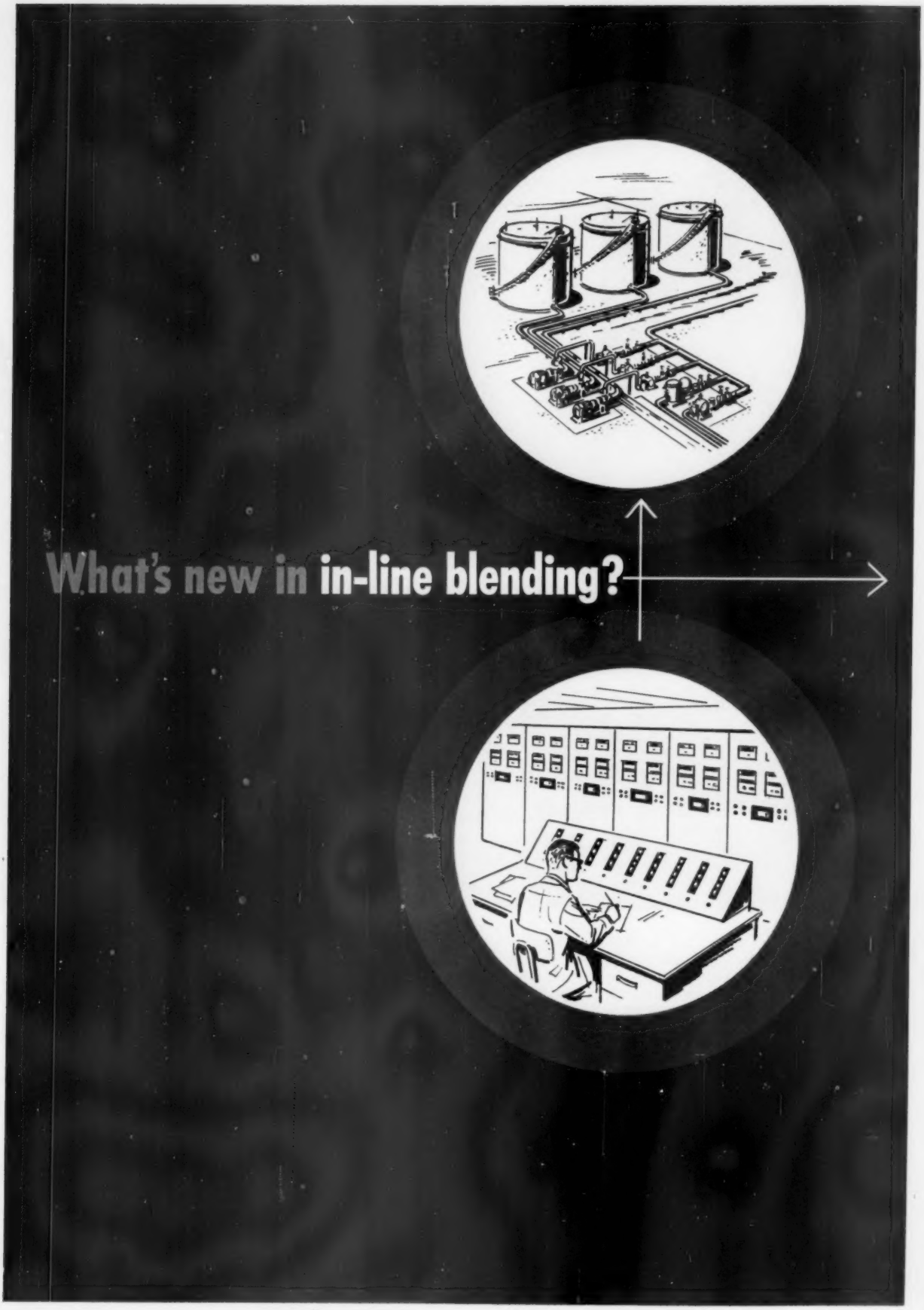
First, the heater had to be large enough to service this giant Cat-Cracker; now one of the largest in operation.

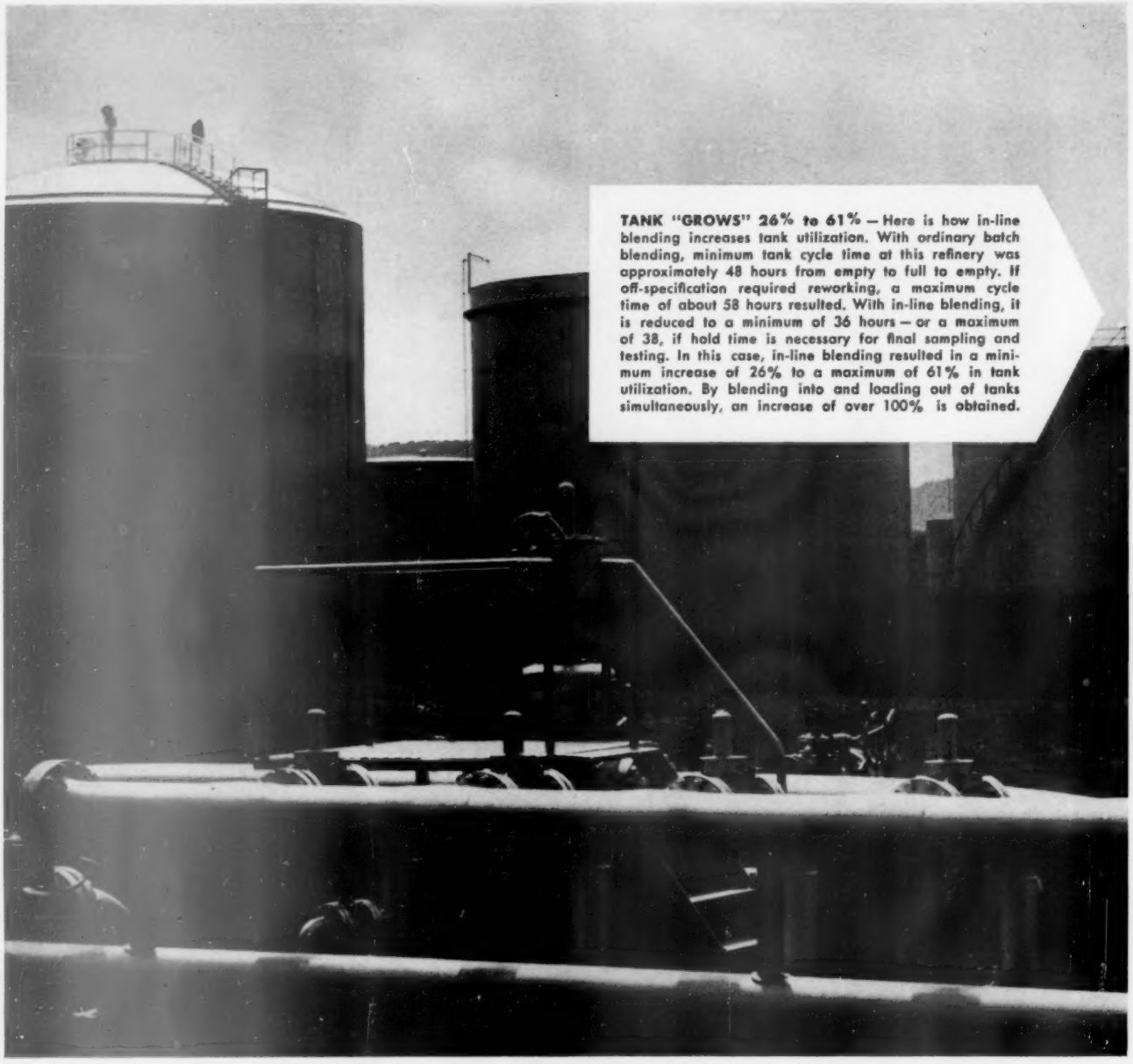
Secondly, Humble wanted a high thermal efficiency, 86% as compared with the usual 75-80%. In the Lummus design, the heater utilizes Ljungstrom Air Preheater and integrated blower and duct system to attain high thermal efficiency. Operating performance has been consistently high. Humble's big fuel savings have more than made up for the slightly higher capital investment for air preheat equipment.

Finally, there was one other difficult design condition. The new heater would be required to operate for long periods without shutting down for maintenance or cleaning. The Lummus design included steam soot blowers which have kept both the bare tubes and studded tube in the convection section clean. The heater fires on heavy residual fuel oil having a very high solids content.

Lummus designs horizontal and vertical tube oil heaters to any size from 100,000 to 300,000,000 BTU/Hour for any process, anywhere in the world. Because Lummus offers *every* type of oil heater, you can be sure that we will recommend the *right* unit for your needs. Consult with Lummus on your next oil heater—large or small.

THE LUMMUS COMPANY, Oil Heater Division, 385 Madison Avenue, New York 17, New York, Houston, Washington, D. C., Montreal, London, Paris, The Hague, Madrid; Newark, N. J.


What's new in in-line blending?



TANK "GROWS" 26% to 61% — Here is how in-line blending increases tank utilization. With ordinary batch blending, minimum tank cycle time at this refinery was approximately 48 hours from empty to full to empty. If off-specification required reworking, a maximum cycle time of about 58 hours resulted. With in-line blending, it is reduced to a minimum of 36 hours — or a maximum of 38, if hold time is necessary for final sampling and testing. In this case, in-line blending resulted in a minimum increase of 26% to a maximum of 61% in tank utilization. By blending into and loading out of tanks simultaneously, an increase of over 100% is obtained.

New In-Line Blending Developments Save Dollars at Existing Refineries

By B. G. Crane

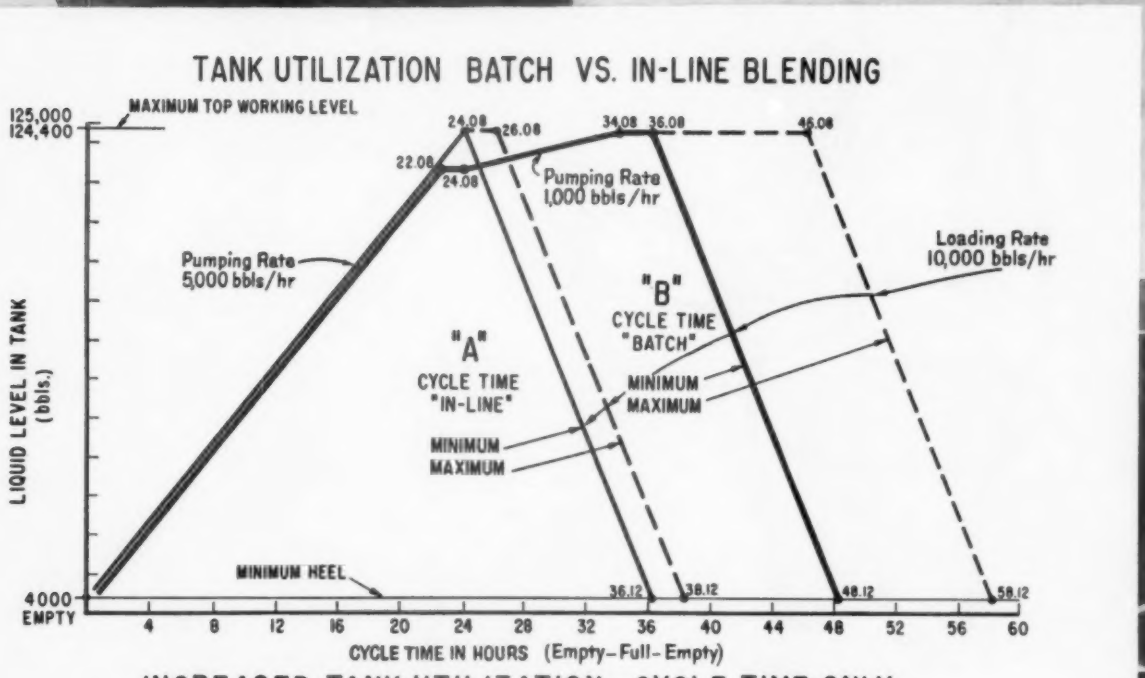
THE ARRIVAL OF ELECTRONICS on the scene has dramatically changed the outlook of in-line blending in the oil industry.

Until now, you had to make such big changes in field piping that most existing refineries could not justify the expense. In-line blending has been adopted at most new refineries, almost as a matter of course, but operators of older plants have had to stand wishfully by.

Now it is no longer necessary to make such extensive piping changes. With electronic control equipment and transmission of signals as digital pulses, you do not have to pipe gasoline components to a central meter station adjacent to a control room.

Other Savings

Not only do you save piping costs, but there are also definite savings in the size, location and installation costs of the control room and control equipment.



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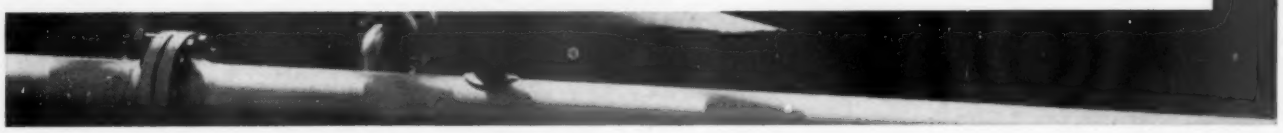

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B. G. CRANE is Manager of Operations for Du Pont's Petroleum Chemicals Division. He has been active in the field of gasoline blending with antiknocks and other additives for nearly 30 years, and has been an active participant in the development of in-line blending techniques. He recently spoke on this subject at a W.P.R.A. meeting, and reprints of his talk are available. If you would like a copy, contact your Petroleum Chemicals Division representative.

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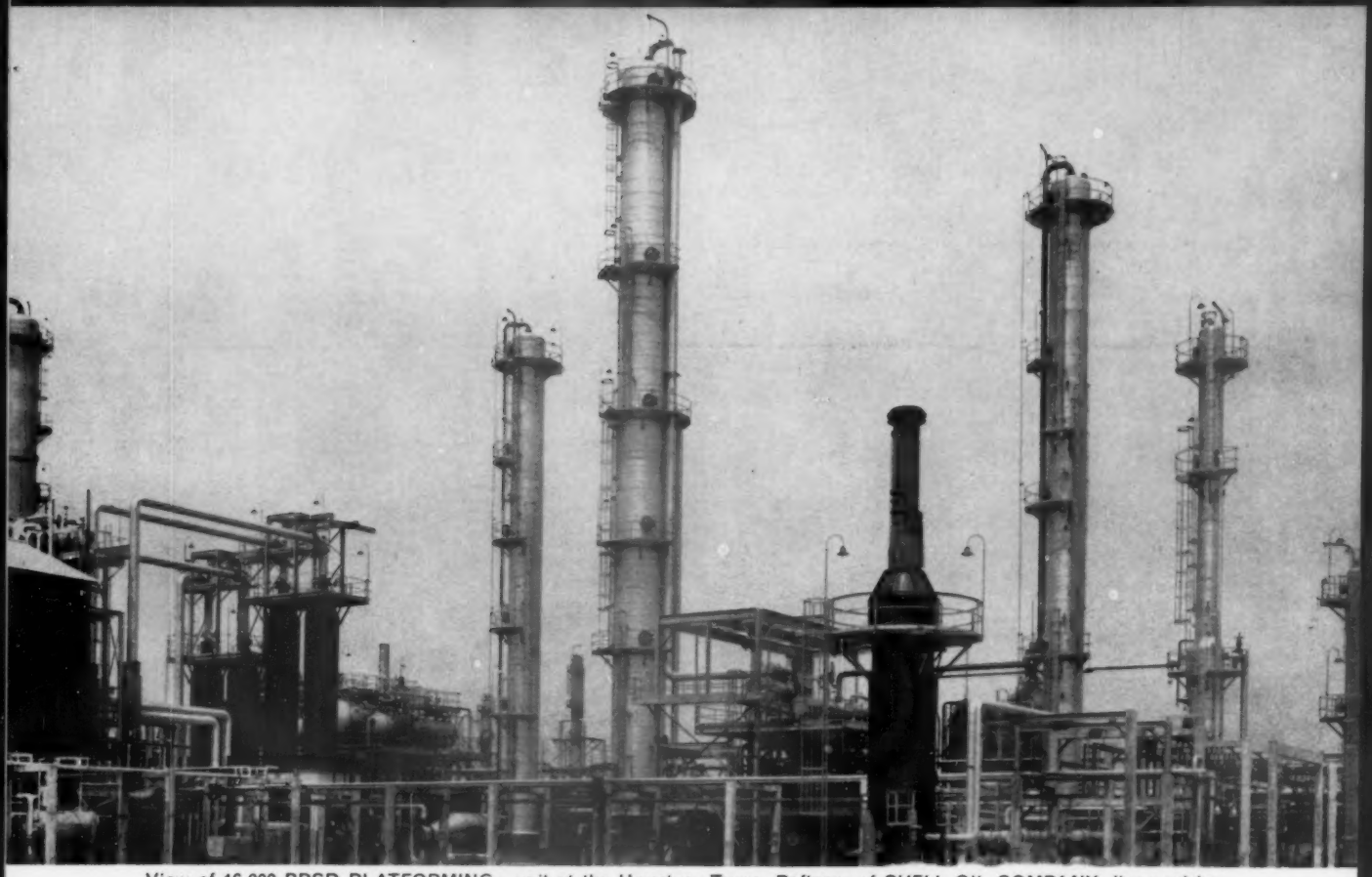

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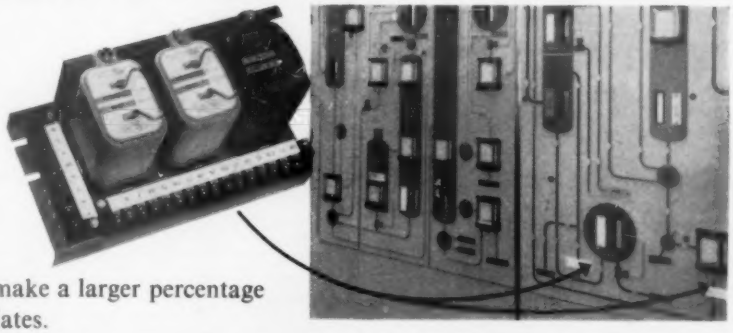

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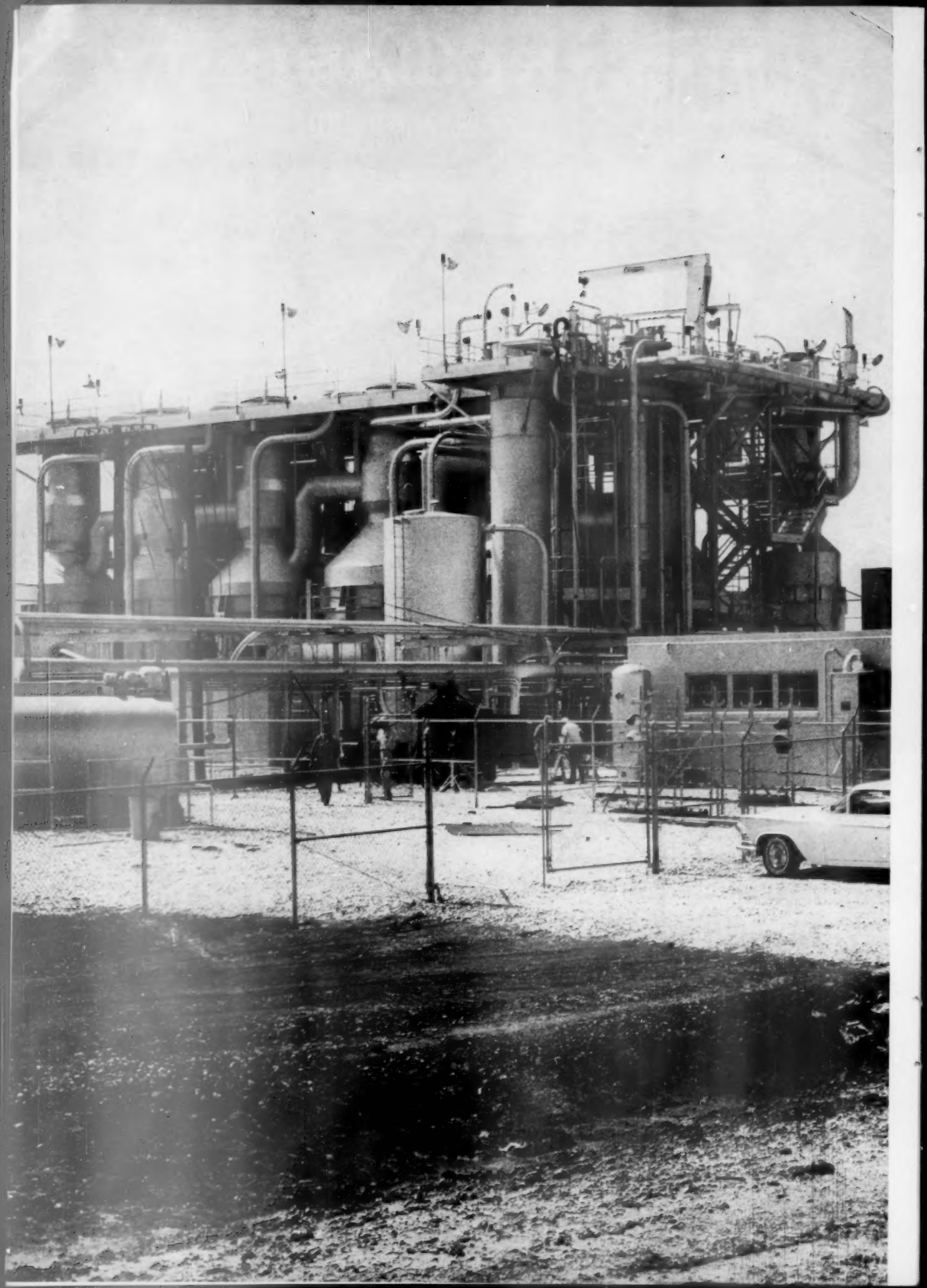

Guest Editor Dr. James R. Fair

Heat Transfer's Great Potential

The purpose of this special issue of PETRO/CHEM ENGINEER is to extend the HPI/CPI engineer's working knowledge of heat transfer and understanding of the important role it will play in his future.

Now, as never before, he can couple improved theory — and its extension to numerical and analog techniques — to high-speed computers and simultaneously better handle the important and ever-present empirical factors.

The HPI/CPI engineer has traditionally taken a somewhat relaxed viewpoint toward heat transfer. A great many of his problems have dealt with forced convection transfer (through tube walls) without phase change. Methods for predicting transfer coefficients have been reasonably reliable, the equipment involved has been fairly well standardized, and the cost of using large safety factors has not been exorbitant.

For the more difficult design problems he has often gone to fabricators where "experience" from many sources has been stockpiled. Here again he has ended up with approximate results, often very conservative, but not particularly annoying after plant startup.

A "low-pressure" attitude toward heat transfer — or any other rate process, for that matter — is a luxury the process engineer can no longer afford. With narrowing plant profitabilities, contingency factors in design must be examined critically. Heat transfer equipment represents a significant capital and operating cost item in the plant. The fundamental and technological background for heat transfer must be properly understood and exploited.

This issue attempts to balance reviews of new developments with initiation of design methods in older areas where no methods have been available previously.

The paper by A. E. Dukler is in the important area of multiphase fluid mechanics and heat transfer. Dr. Dukler treats the case of liquid films flowing over solid surfaces and provides design methods for predicting heat transfer rates. The reader will recognize immediately such typical process applications as falling-film evaporators, knock-back condensers, and thermosiphon reboilers.

The paper by O. K. Crosser deals with unsteady-state heat transfer between solids and fluids in packed beds. In his development of design methods, Dr. Crosser presents an example calculation of interest to many in the HPI—determination of break-through when regenerating a solid-bed dehydrator with a hot purge gas.

The paper by J. W. Westwater considers the ever-vexing problem of predicting reliable values of heat transfer coefficients for nucleate pool boiling. In particular, Dr. Westwater reviews and analyzes the many recent attempts to correlate boiling coefficients. and discusses the many variables influencing rate of transfer. He gives the engineer advice on how to proceed at this time, and also offers some comments on the probable course of research in boiling transfer.

The paper by your guest editor presents quantitative design methods and transfer coefficients for direct-contact gas coolers. The paper considers equipment normally encountered by the process engineer — spray chambers, baffle and tray columns, and packed columns. Mass transfer effects are taken into account, and commercial-scale performance data provided.

Two additional papers in connection with this symposium are scheduled for publication in subsequent issues.

■

♦ Sea water conversion plant at Freeport, Texas, recently completed by Interior Department's Office of Saline Water uses 12 falling-film type evaporators.

Nucleate Pool Boiling

by Dr. J. W. Westwater

The design engineer can benefit from a number of new nucleate boiling correlations that have resulted from the enormous amount of research on boiling heat transfer in the past 10 years.

Design of heat exchangers to handle boiling liquids is purely a matter of empirically devised formulas coupled with know-how, since there are no proven physical principles on which a design can be based.

Primary research attention has been focused on nucleate boiling since it permits extremely high fluxes in comparison to transition boiling and film boiling. Any increase in the temperature difference driving force, ΔT, causes an increase in the heat flux (except at the peak flux), which is desirable for process control. Transition boiling, on the other hand, results in a decrease in flux with an increase in ΔT, and control becomes more difficult. Film boiling also poses some control problems, mainly because a real minimum occurs in the flux vs ΔT relationship.

Nucleate pool boiling is boiling carried out in the simplest manner possible. The fluid is a pool of liquid with its bulk at the saturation temperature. No forced convection is employed. The heat source is a hot solid surface, and in this article the liquid is considered to be a single pure component. To simplify further, neither the initiation of boiling nor the peak in the boiling curve will be covered here.

The problem is to express the functional relationship between the heat flux and the imposed operating conditions during nucleate boiling. If this cannot be done, the more complicated cases cannot be mastered.

That the design of boiling equipment requires empiricism is no cause for special apology. None of the convective heat processes can be handled by straight analytical techniques. Conduction heat transfer and radiation heat transfer are processes which are amenable to mathematics, but even these require empiricism. Thermal conductivities and emissivities are coefficients (found experimentally) which must be used in the basic equations.

Variables

The number of possible variables is staggering when one considers boiling in the most general sense. We are not sure which of the proposed variables are real and which are of no consequence. In fact, some unsuspected parameters may need to be added to the list.

Suppose liquid containing some vapor is in relative motion past a hot solid of undefined shape. What will be the rate of heat transfer to the liquid? The shape of the solid is un-

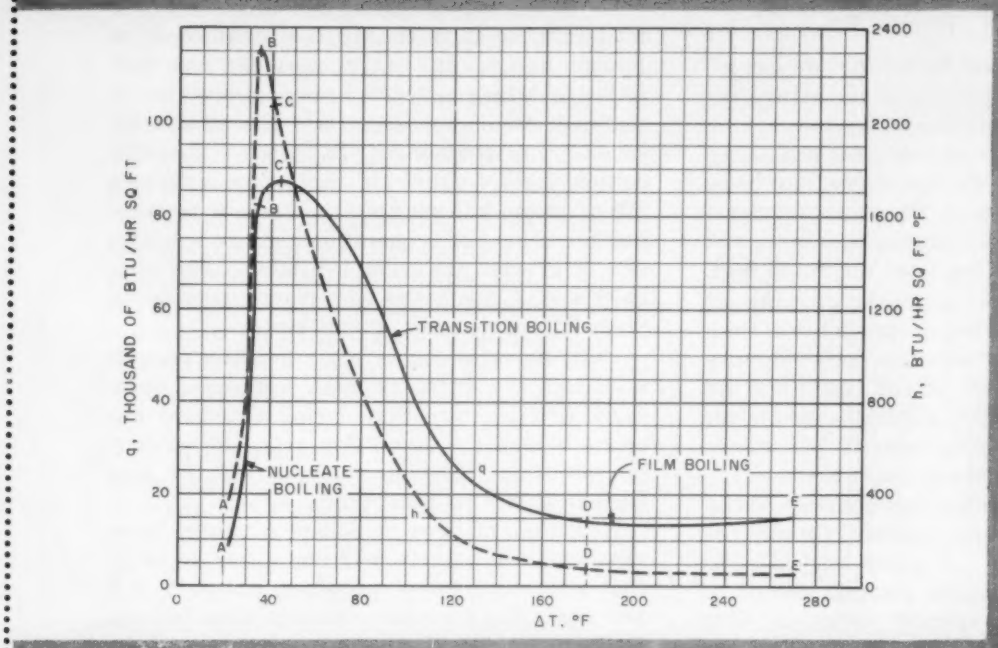

FIG. 1. Two methods suitable for expressing boiling data. Isopropanol on a ¼-in. copper tube.[4]

doubtedly important. It is for all convective processes. The relative velocity between the liquid and the solid and between the vapor and the solid seems important. The fact that the liquid and vapor velocities will be different (the difference is called the slip velocity) is a matter of deep concern. The temperature difference driving force is obviously a prime variable, but even this can be complex.

For example, if water at 212 F at atmospheric pressure is in contact with a hot solid at 252 F, the ΔT is 40 F. However, the resulting heat flux is not the same as when a ΔT of 40 F is achieved with water at a bulk temperature of 202 F in contact with a solid at 242 F. The latter case is subcooled boiling. In designating the boiling side ΔT, one must specify how much of this is above the saturation temperature and how much is below.

The type of liquid used is significant. This is an indirect way of saying that some of the physical properties of the liquid and vapor must be important.

In a recent article Hughmark[1] lists 32 variables that occur to him for nucleate boiling. For the liquid they include the density at the bulk temperature and at the superheated temperature, the viscosity at each temperature, the surface tension at each, the specific heat at each, the thermal conductivity at each and the latent heat of vaporization of each. For the vapor, properties listed are the density, viscosity, specific heat and thermal conductivity at each of the two temperatures. Other parameters included are the difference in the liquid and vapor density, the wall temperature, saturation temperature, the two reduced temperatures, the vapor pressures at the two temperatures, the two reduced pressures and also the ΔT and the Δp.

Hughmark did not include a number of possible factors such as the contact angle, the coefficient of expansion, size of the heating surface, the acceleration of gravity, size of the surface pits, the size of the break-off bubbles, the amount of subcooling, the velocity of the liquid or vapor or the slip velocity.

If all of these are significant we are faced with a desperate situation. Dimensional analysis, with mass-length-time-temperature, will give 38 dimensionless groups. Relating these properly would be a monumental, discouraging task.

May thermodynamics be used to relate variables to one another and thus reduce the number of parameters to be studied? One of the vexing features of boiling is the inapplicability of thermodynamics. All transport processes, including heat transfer, are non-equilibrium processes. Thus thermodynamics, the science

of equilibrium processes, is of very limited use for these.

Although a liquid may be boiling, we cannot believe that all of the liquid is at the saturation temperature. The liquid close to the heat source is always superheated; the liquid far away may be subcooled. Vapor in the liquid need not be in equilibrium with the liquid. The vapor temperature can be any value within the maximum and minimum temperature limits of the liquid field.

The pressure inside a bubble growing or collapsing in a liquid is not predictable from thermodynamics. This pressure does not have to be the vapor pressure of the liquid nor the ambient pressure. In fact, a bubble could never grow or collapse at finite rates if the bubble pressure were exactly the ambient pressure.

One approach to eliminating spurious variables is laboratory experimentation. Usually the experimenter controls as many variables as possible and then examines the test results to decide the effect of specific variables. This sounds straightforward, but in practice one may not be able to prevent confounding.

For example, what is the effect of pressure (just pressure, no other variable) on boiling? Tests with water at pressures up to 2000 psi are available. However, the physical properties of saturated water and steam change drastically over the accompanying temperature range.

Are the changes in the heat transfer rates caused by the pressure per se, or are they caused by the changes in viscosity, density, surface tension, latent heat of vaporization, etc?

This issue is not resolved. Some workers believe pressure is a parameter.

For example, it is included in Eq. 1, 4, 8 and 10, given later. Other persons believe that the only role of pressure lies in its influence on the boiling temperature and physical properties of the fluid. This writer favors the latter view.

To prove experimentally, in an unequivocal manner, whether pressure per se is a parameter, one may consider either of two imaginary programs. One would require tests made at two or more pressure levels with a liquid whose physical properties were independent of pressure. No such liquid exists. The alternate scheme is to select two liquids whose physical properties are identical when one liquid is boiling at a specific pressure and the second liquid is boiling at a different pressure. The only difference in the two test conditions would be the pressure. The chances of finding two such liquids are quite remote. No practical direct experimental method is available for separating the effect of pressure from the effects of physical properties.

The usual way of testing the effect of physical properties is to change the pressure or to change liquids. In either case, not one but rather a whole set of physical properties is changed simultaneously. Thus the effects invariably are confounded. In spite of the difficulties, tests do indicate that some variables are of prime importance (the surface texture, the latent heat of evaporation and the acceleration or gravity are examples) while some variables are of much less importance (the vapor viscosity seems to be in this class).

Early experiments were not sensitive enough to detect the effect of weak variables. Some early writers state that during subcooled nucleate boiling the liquid flow rate, the amount of subcooling and the geometry of the test surface are of no importance.

Now that millions of dollars worth of tests are behind us, ample evidence exists to show that all these are real variables, although at a low level. Many nuclear reactors have boiling-water cooling designed to take advantage of the helpful aspects of velocity and subcooling.

Although the effects of geometry are weak, they are real. For example, one set of tests[2] involved the use of a steam-heated bayonet tube immersed in boiling methanol. The apparatus could be rotated by 90 deg. Tests also have been made[3] with liquid boiling on one face of a heated ribbon. The heater could be oriented to present the face up, down or vertical. The results were a function of the geometry. Face up gave the greatest heat flux and face down the smallest, both at the same ΔT.

Other geometry effects one must include are the equivalent diameter of a flow channel and the length-to-diameter ratio. Data seems to show that these are real but weak variables.

Expressing Boiling Curve

When heat is to be transferred by nucleate boiling under controlled conditions one must decide to control either the heat flux, q, or the ΔT. Thus one of these is selected as the independent variable and the other is dependent. Fig. 1 shows smoothed curves representing published data for a 1-gal pool of isopropanol boiling on a steam-heated copper tube.[4] The independent variable is ΔT. Although arithmetic coordinates are used here, the choice is immaterial. Logarithmic coordinates are quite satisfactory.

Region ABC represents nucleate boiling. Point C corresponds to the maximum heat flux. Actually the maximum flux extends over a range of ΔT from about 40 to 50 F. The heat transfer coefficient, h, is shown also in Fig. 1.

The maximum h is not a flat region; rather it is a very sharp value occurring at a ΔT of 36 F. An interesting point which is overlooked by many persons is that the maximum h and the maximum q do not occur simultaneously.

Transition boiling is in the Region CD and film boiling occurs in the Region DE and beyond E. Illustrations of the appearance of the different modes of boiling are available elsewhere.[5]

Use of graphs of h vs ΔT is common, but q vs ΔT seems more desirable. Although h reaches a sharp peak at some ΔT, no special importance can be attached to either this h or the ΔT. This h does not correspond to the maximum heat duty for equipment, and it does not correspond to the burnout point for equipment using q as the independent variable. The maximum h has a trivial meaning. It corresponds to the point of tangency of a line drawn from the origin (using arithmetic coordinates) to the q vs ΔT line. This has no special significance for design purposes. A more crucial design criterion is the peak heat flux.

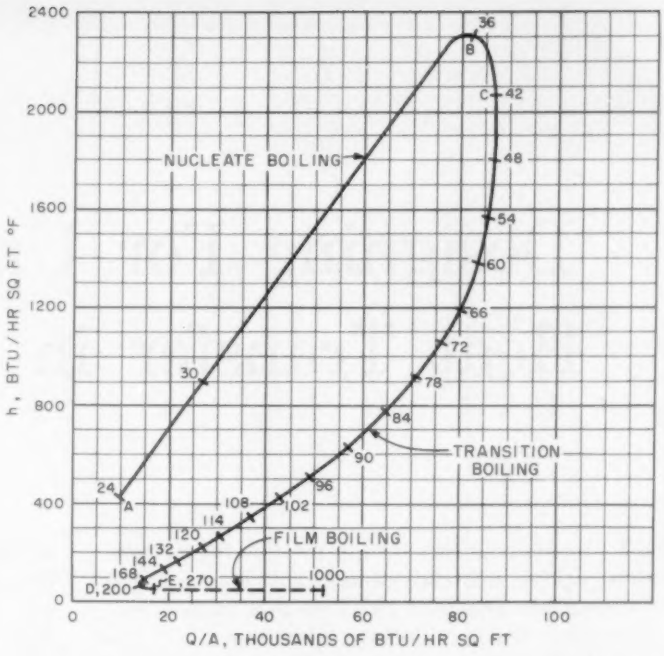

FIG. 2. An undesirable method for graphing same data as in Fig. 1. Numbers along the curve are the ΔT. The film boiling curve beyond Point E is calculated.

Fig. 2 shows a third way of graphing pool boiling data. It is very popular in the USSR and Japan and is common also in the United States. Points A through E on this graph are the same points shown in Fig. 1. Here it is obvious that the maximum flux (Point C) and the maximum h (Point B) occur at different conditions.

This type of graph stretches out the nucleate boiling data in such a way that a straight line usually looks like a good fit. However, a variety of non-linear relationships between q and ΔT give nearly straight lines when expressed as q vs h. This means that a correlation that looks good for q vs h may not look good for q vs ΔT.

McAdams[6] points out that q vs h should be discouraged. His main point is that test data which shows a real scatter when plotted as in Fig. 1 may superimpose nicely or line up rather smoothly, thus giving a false impression of high accuracy and good reproducibility when plotted as in Fig. 2.

The use of q vs h will probably decline rapidly when its proponents begin to make tests in transition boiling or film boiling. With this type of graph the transition region is stretched over a long Region CD, and the temperature scale compresses as one goes from C to D. The numbers along the line show the values of ΔT. The film boiling region is highly compressed in Fig. 2. The space needed to show nucleate boiling data for a ΔT change of 12 F, the distance from A to B, is more than 200 times the space for an equal ΔT change in film boiling. Therefore the recommended method for representing pool boiling data is with q as a function of ΔT.

Selected nucleate boiling equations published since 1952 will be discussed in Part 2 of this article, to appear in September.

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by Dr. O. K. Crosser

Designing For Unsteady-State Heat Transfer in Packed Beds

A time-saving new design method for vessels that utilize unsteady-state heat transfer between gases and solid particles in a packed bed also offers these important advantages:

1. It can accommodate most of the complications which might occur.
2. It provides a fundamental basis for analysis of data from a particular unit.
3. The same equations describe both the heat transfer and mass transfer cycles and even certain combined operations.
4. Detailed mathematical analysis is not required. It usually is not economical to spend a great deal of time on this in view of the uncertainty to design data.

Packed-bed operations usually consist of three basic steps:

In step 1 the cool, clean bed is loaded by passing the process steam through the fixed bed, which removes the adsorbables. The desired type of separation is achieved by using the correct adsorbing time, which depends upon the relative affinity between the fluid constituents and the adsorbent.

In step 2 the bed is heated by flowing superheated steam or other hot gas through the bed. This removes the adsorbed material by stripping action and by taking advantage of the lower equilibrium constant for the bed at higher temperatures.

In step 3 the bed is cooled either by passing a cool material (sometimes the raw feed stream) through the bed or by surrounding air until nearly ambient or other fluid temperatures are obtained.

The sequence is then repeated.

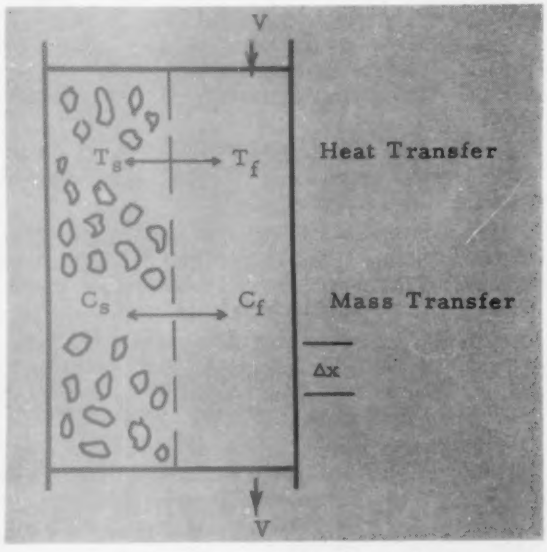

FIG. 1. Section of packed bed.

Development Of Solution

The outline of the packed bed behavior for any one of the three steps is indicated in Fig. 1. Usually only one transfer process will be important in any step, but both heat and mass transfer will always occur.

These processes may be described mathematically via balance equations for adsorbed components and energy for the bed volume indicated in Fig. 1 for both the fluid and solid phases. Only the heat transfer process will be discussed here. For the energy balances one obtains:

$$\rho_f Cp_{f\varepsilon} \frac{\partial T_f}{\partial \theta} = -v_\varepsilon \rho_f Cp_f \frac{\partial T_f}{\partial x} + ha(T_s - T_f) \quad . \quad (1)$$

$$\rho_s Cp_s (1-\varepsilon) \frac{\partial T_s}{\partial \theta} = -ha(T_s - T_f) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where T is the temperature, ε is the porosity, x is the distance from the entrance to the bed

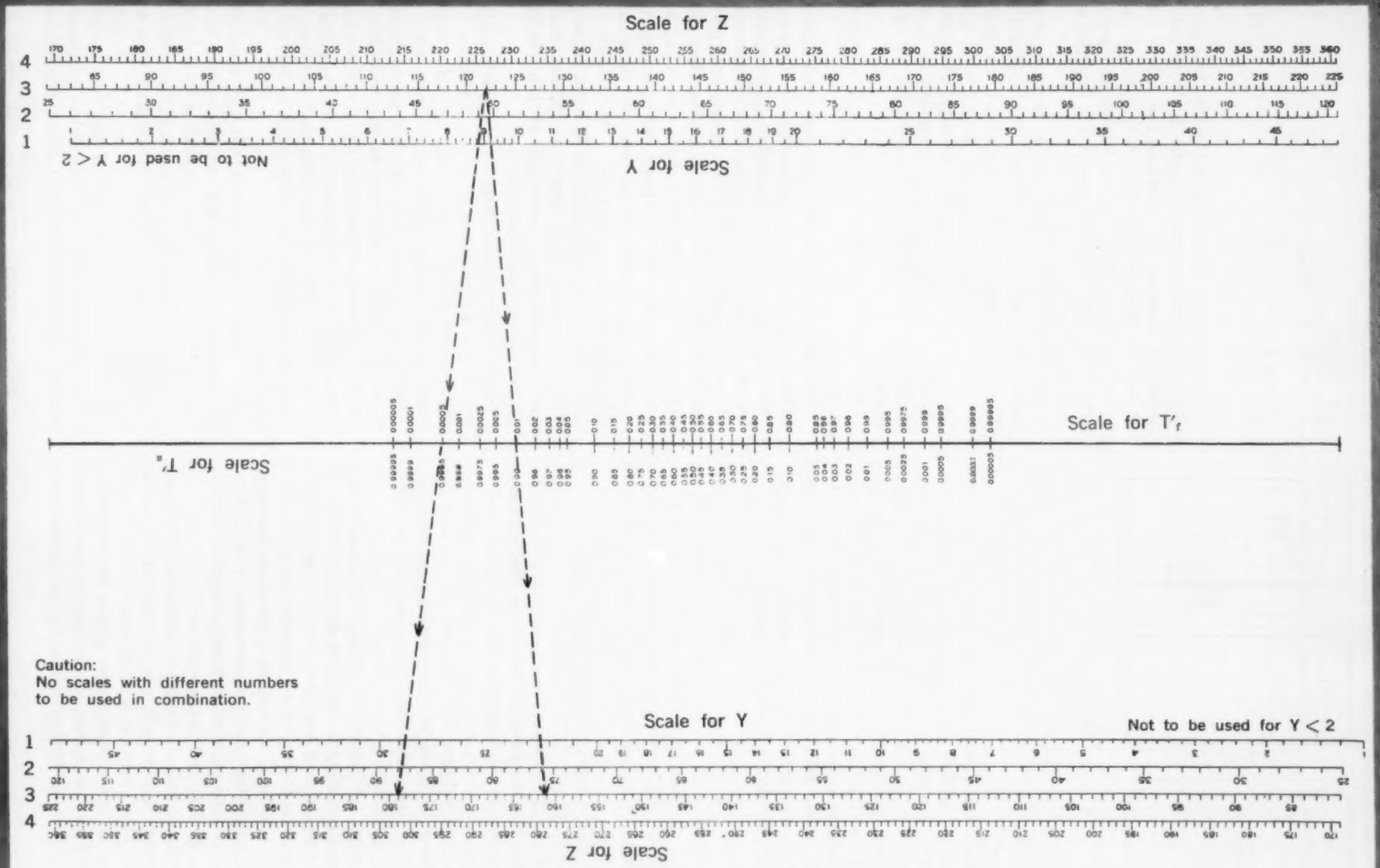
Scale for Z
Not to be used for Y < 2
Scale for Y
Scale for T'a
Scale for T'f
Caution:
No scales with different numbers
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FIG. 2. Nomograph for calculation of T'_a and T'_f, given Y and Z.
(With permission of American Chemical Society)

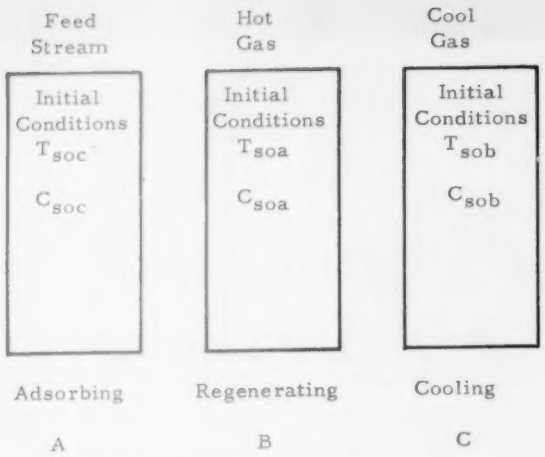

FIG. 3. Bed conditions and operation sequence.

in feet, θ is the time in hours, v is the fluid velocity through the void space (superficial velocity/porosity) in feet per hour, ρ is the density, C_p is the heat capacity, ha is the heat transfer coefficient as heat transferred between solid and fluid per unit time per degree F per foot of bed length, and the subscripts (s and f) refer to the solid and fluid phases respectively.

It is convenient to use primed symbols to obtain the dimensionless variables:

$$x' = x/L$$

$$\theta' = \theta v/L$$

$$T'_f = \frac{T_f - T_{so}}{T_{fI} - T_{so}}$$

$$T'_s = \frac{T_s - T_{so}}{T_{fI} - T_{so}}$$

where the subscript o refers to the original condition at the beginning of the cycle, and I refers to the injection or entrance condition. L is the total length of the bed.

These two sets of simultaneous partial differential equations are the subject of a tremendous literature.[3,8,18,23]

Design procedures in this article assume all properties constant, constant plug-flow velocity, an adiabatic and constant transfer coefficients. For gas contacting solid adsorbents with relatively low (10% maximum by weight) loading, these conditions are met remarkably well. The same is true of many liquid contacting operations, such as ion exchange.[23]

This solution ignores the influence of mass transfer; however, it can be applied to cases where this assumption is unwise.

For design purposes, the approximation suggested by Klinkenberg[14] is extremely useful and is shown as a nomograph in Fig. 2. Values for T'_s and T'_f are presented as functions of the dimensionless groups:

$$Z = \frac{haL(\theta' - x')}{\rho_s Cp_s (1-\varepsilon)v} \quad \ldots\ldots\ldots\ldots \quad (3)$$

$$Y = \frac{ha\,L\,x'}{\rho_f Cp_f\, \varepsilon v} \quad \ldots\ldots\ldots\ldots \quad (4)$$

The symmetrical nature of the solutions permits the one nomograph to solve for both variables for each set by inverting the values for Y and Z. This is indicated on the graph by labeling the scales to be read from the same side of the page as the appropriate dimensionless temperature.

Fig. 2 is a generalized plot of the temperature-time history of the bed for arbitrary original temperature and fluid injection temperature as a function of the properties of the fluid and solid and the fluid velocity. This permits the designer to study a variety of conditions for the operation of each cycle of bed operation.

The general sequence of operations is shown in Fig. 3.

The solution assumes uniform conditions throughout the bed at the start of each cycle. This may be a violent restriction, particularly for the change from Cycle C to A when the feed stream is used for cooling. Completely arbitrary initial conditions could be used[3] but this will not usually be justified for preliminary calculations. The beds will undergo some transient changes in condition when they are first put into operation.

As the cycling continues a dynamic steady state is reached. The time required to reach such a condition is especially of interest in packed bed regenerators.[12]

Since these studies indicate that relatively few cycles are required even for conditions of extreme difference between startup and steady state operation, this effect will be ignored.

Eq. 3 and 4 indicate the information required to calculate bed designs for various operating conditions to obtain desirable results: the heat transfer coefficient; interstitial velocity, porosity or void space; contact area per unit tower volume, and the thermal properties of the fluid and solid.

The design procedure conveniently consists of choosing a cycle time, a bed length, and setting x′ equal to 1 (corresponding to the end of the bed). A graph is then quickly plotted as the solid temperature as a function of time at the end of the bed.

The porosity of the packed bed has a profound influence upon its performance. Measurements in the field as well as standard procedures

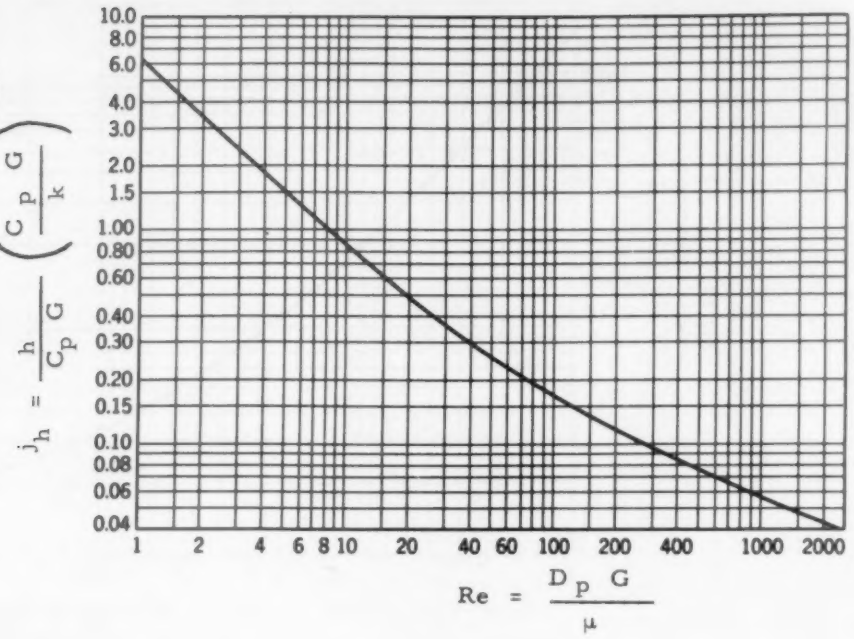

FIG. 4. j_h as a function of Reynolds number. Reprinted with permission from Bird, R.; Stewart, W.; and Lightfoot, E.: *Notes on Transport Phenomena*, Fig. 21; 1958, John Wiley & Sons, Inc.

for packing are very desirable. Manufacturers of solid packings or adsorbents will usually supply such data upon request. Factors to consider are the particle diameter to bed diameter ratio, particle shape, roughness of particle surface, and particle size distribution in addition to the procedure for packing the bed. Reproducible conditions are easiest to obtain as random arrangements when the bed is filled slowly with an occasional jolting of the container or stirring of the top few inches of bed.

The porosity, including the influence of particle-bed diameter ratio, can be estimated as:[2a]

$$\varepsilon = 0.435 \frac{D_p}{D_T} + 0.442 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Particle shape can be included if D_p is the "equivalent" diameter. This is the diameter of a sphere having the same area of an average particle. D_T is the tube diameter. Other effects are also partly accounted for by Eq. 5, but actual measurements are the only safe procedure for particles of unusual shape or roughness.

Contact Area

The transfer area per unit of tower volume is usually estimated as if the particles were spheres:

$$a = \frac{6(1-\varepsilon)}{D_p} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

For other shapes Campbell[2b] recommends:

$$a = \frac{0.305A}{D_p \varepsilon V^{2/3}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where A and V are the area and volume of an average particle. Campbell also presents data or packing characteristics for several materials. Similar expressions are suggested by Gamson.[9]

Heat Transfer Coefficient

Heat transfer coefficients in packed beds have been the subject of many excellent studies. Radial conductivity, longitudinal conduction and dispersion, radiation and velocity effects all influence the effective heat transfer coefficient. The most convenient result of general utility is that of Gamson et al[9] which is presented as Fig. 4. D_p is the same equivalent particle diameter; k and μ are the thermal conductivity and viscosity of the liquid; G is the superficial (based upon tube area) fluid mass velocity.

Pressure drop studies for packed beds can be correlated as shown in Fig. 5[6]. It is usually convenient to assume random packing with some allowance for particle shape.[1] The same "effective" particle diameter can be applied to approximate the shape effect upon the friction factor. For particles of very non-spherical shape (sphericities below 0.85), the procedure of Brown[1] should be used. For most designs, large pressure drop cannot be allowed and the design calculations act primarily as a guide

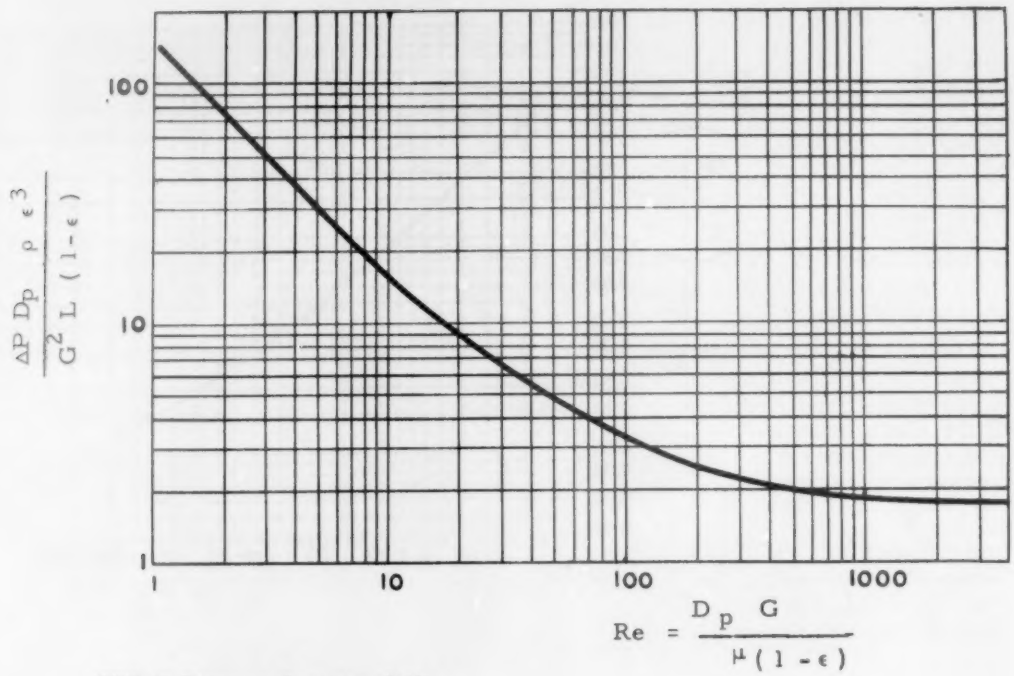

FIG. 5. Pressure drop correlation.

for restricting bed length to diameter ratio to give low values of pressure drop.

Application To Design

As an example, assume a bed of silica gel 2 ft in diameter and 10 ft long has been uniformly loaded to saturation and contains 10 lb of water per 100 lb of gel, all at an original temperature (Tso) of 100 F. The bed will be regenerated with dry methane heated to 400 F. The gel particles have an average particle diameter of ¼ in. Interstitial velocity will be chosen as 0.5 ft per sec. The bed operates at 500 psia.

In the regenerating cycle, the bed is heated to some higher temperature where the equilibrium constant for the adsorbing component is significantly lower. The simplest calculation ignores the influence of factors other than the heat capacity of the bed and the proper variables are those of Eq. 3 and 4.

The bulk void fraction is given by the manufacturer[4] as 0.4. This does not include "pore" volume which is important for mass transfer considerations but which should not be included for pressure drop or contact area calculations. Comparing this value with Eq. 5 shows there is about a 10% effect because of the irregular shape of the particle.

The area of contact is estimated from Eq. 6 as:

$$a = \frac{6(1\text{-}0.4)(12)}{(0.25)} = 172.5 \text{ sq ft/cu ft}$$

This is, of course, not the "specific area" or "specific surface" frequently reported which is determined by adsorption measurements. The irregular shape generally increases (a) since $A/V^{2/3}$ is a minimum for a sphere, so that the area calculated by Eq. 6 will be conservative. This approximation should be acceptable unless the particles are very nonspherical. Cylinders with a length to diameter ratio of 1.15 indicate an area about 16% larger according to Eq. 7.

The heat transfer coefficient calculation is begun by computing the Reynolds number. The density and viscosity of the gas are calculated from the generalized compressibility factor and reduced viscosity plots.[22]

Methane:

Critical temperature −116.5 F, (343R)

Critical Pressure 673.1 psia

Reduced temperature (average):

710/343 = 2.06

Reduced pressure (small pressure drop):

500/673 = 0.744

$\mu_r = 1.0$

Z = 1.0 (compressibility factor)

μ = 0.0113 Centipoise

$$\rho = \frac{500(16)}{(10.72)(710)} = 1.05 \text{ lb/ cu ft}$$

The superficial velocity $= v_\varepsilon = (0.5)(0.4)$
$= 0.2$ ft/sec

and

$$Re = \frac{(0.25)(0.2)(1.05)}{(12)(0.0113)(0.000672)} = 580$$

From Fig. 4:

$$j_h = 0.072$$

and

$$h = C_p G \left(\frac{C_p \mu}{k}\right)^{-2/3} (0.072)$$

C_p = 0.6 Btu/lb at 250 F
k = 0.022 Btu/hr-sq ft-F/ft

Thus,

$$h = \left\{\frac{(0.6)(0.2)(3600)(1.05)}{(0.022)}\right\}\left\{\frac{(0.6)(0.0113)(2.42)^{-2/3}}{}\right\}(0.072)$$

h = 32.6 Btu/hr-sq ft-F

From the manufacturer[4] p_s (particle) = 75 lb/cu ft and C_{ps} = 0.22 Btu/lb F

For calculating T_s' (at L = 10 ft) we have from Eq. 3 and 4

$$Z = \frac{(32.6)(172.5)(10)(\theta'-1)}{(75)(0.22)(1.-0.4)(0.5)(3600)} = 3.16\ (\phi'-1) \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$Y = \frac{(32.6)(172.5)(10)(1)}{(1.05)(0.6)(0.4)(0.5)(3600)} = 122$$

Y and Z must be of the same order for calculation to be appropriate. The numbered scales must always be paired in using Fig. 2. When either Y or Z lie beyond this range, it implies either that no change in temperature has occurred, or that whatever change is possible has been completed.

In this case, using Y = 122 in Fig. 2, we find that for $T_s' = 0.99$, ie., within 1% of the total possible change at infinite time, Z is (use Scale 3) 161 whence $\theta' = \frac{161}{3.16} + 1 = 52$

and

$$\theta' = \frac{52(10)}{(0.5)(3600)} = 0.289 \text{ hr or } 17 \text{ min}$$

at $T_s' = 0.9995$ (use scale 3); Z = 179 and θ = 0.32 hr or 19 min.

This shows the temperature wave will be quite sharp, and that 20 minutes' contact time effectively heats the entire bed. A series of values of θ' and T_s' can be obtained to show the shape of the temperature profile instead of merely estimating a total time requirement. Except very near the entrance, the position of the wave can be located by using values of x' below unity.

An identical procedure serves to calculate the cooling cycle using dry, cool, purge gas. If the cooling fluid is a different material, the new values for the heat transfer coefficient and properties must be introduced.

Other Heat Effects

The most important attribute of the solution presented as Fig. 2, is the ease with which other effects can also be accounted for. During the regeneration cycle, the best of adsorption of the adsorbing component and the heat capacity of the bed vessel may be significant. In the example, the energy required to vaporize the adsorbed water is at least 10,000 Btu/100 lb gel. Furthermore, the wall of a vessel for pressure operation will also have a heat capacity. The size of both effects can be estimated per pound of bed.

Water adsorbed = 0.1 lb water/lb bed
Heat of adsorption = 1300 Btu/lb water
Total energy required = 130 Btu/lb bed
A 24-in., 500-lb vessel wall is about ½ in. thick with a heat capacity of 0.12 Btu/lb-F.
Volume of 1-lb packed bed = 1/45 = 0.0222 cu ft.
Length of bed = (0.0222) / (4π/4) = 0.00706 ft = length of vessel.

Heat capacity of vessel: $\pi D t \rho C_p = \pi(2)\frac{(0.5)}{12}(0.00706)(489)(0.12)$
= 0.1085 Btu/F
Heat capacity of bed = 0.22 Btu/lb.
Total energy required = $C_p \Delta T$ = (0.22 + 0.1085)(250) = 82.5 Btu/lb bed.

Thus, for this case, the vessel contributes about 50% more energy than the bed requires and the latent heat is more than half the total requirement. For adsorbed hydrocarbons, whose latent heats are about 200 Btu/lb, the effect is smaller but not negligible. In some installations, the inside of the vessel is insulated to avoid its heat requirements. This requires a larger vessel, but it sometimes is economically justifiable.

The figure of 10 lb adsorbed water per 100 lb of adsorbent is often referred to as the "dynamic" adsorption. This means that this amount can be continually adsorbed and removed by regeneration, then readsorbed. This is, therefore, the difference between the equilibrium adsorbtion at loading temperature and that at regenerating temperature.

Obviously, if the equilibrium is not favorably influenced by temperature the regenerating gas need not be heated. The effect of latent heat can therefore be accounted for as an additional heat capacity by changing C_{ps} in Eq. 3 to:

$$C_{ps}' = C_{ps} + m\Lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

where Λ is the heat of adsorption (estimated if necessary from the heat of vaporization) and m is the temperature slope of the adsorption isobar.

A simplification, justifiable as a first order approximation, is to divide the mass removed by the regeneration cycle by the temperature increase of the bed during regeneration. Many equilibrium constants are virtually linear for the temperatures involved, so this assumption should be acceptable.

For the example, this term is:

$$C_{ps}' = 0.22 + 0.1085 + \frac{130}{250} = 0.85$$

The new value for Z is (refer to Eq. 8):

$$Z = 0.83\ (\theta'-1)$$

whence for $T_x' = 0.99$, $\theta = 1.1$ hr. For the conditions of the example, the cycle time is nearly proportional to changes in the total heat capacity, and the value of internal insulation or smaller bed loading can rapidly be calculated. Heat loss from the vessel can be accounted for by relating the heat loss per cycle to the bed heat capacity by the same method used to allow for the heat transferred to the vessel.

Economic designs include consideration of costs of pressure drop, vessel and adsorbent. Vessel design is usually referred to the ASME Codes[11]. The influence of velocity, fluid properties and bed length is easily computed using the method described.

The Use of Field Data

Some situations demand a trouble-free installation. In such cases, the value of field testing cannot be over emphasized. The actual value of breakthrough time is very important and provides the best estimate of how serious aging or accidental effects could become. Such tests are expensive, but in terms of the confidence of a sound design the cost may be justified.

In terms of the design procedure, such data can be applied to the design criteria used. Values computed for the parameters in Z and Y can be obtained by fitting the breakthrough curve of temperature as a function of time by trial and error, or other straight forward approaches.[13] The influence of velocity can be almost completely determined from two tests. The assumption of plug flow is often of great concern especially on the mass transfer cycle. The shape of the breakthrough curve is affected both by the heat transfer coefficient and the velocity dispersion. For detailed analysis and the comparison of dispersion results, references[17,13,24] should be consulted. These effects are usually more important for the mass transfer cycle.

Fig. 2 also provides the best way of estimating performance when only part of a bed is to be used from the breakthrough curve for the entire bed. Values of the parameters determined can be applied to future designs as well as a test for the values assumed in the design in calculations. Once the experimental values for the coefficients in Z and Y are determined by a breakthrough curve, very good estimates of time requirements for partially heating a bed can be made.

Closed Cooling Systems

In many applications, particularly dehydrating processes, the cooling cycle is accomplished by stagnant heat transfer to the surroundings. In such "closed" processes the cooling cycle may easily control the overall cycle time. For this calculation the bed is considered an infinite cylinder or other appropriate shape with surface heat transfer resistance and the Gurney-Lurie charts[22] applied. These are also available in standard texts on heat transfer.

The thermal diffusivity of the bed is calculated using the arithmetic average density (including void space) and heat capacity and the "effective" thermal conductivity. Effective thermal conductivities have been the subject of numerous studies. Eq. 10 is an adequate expression for a stagnant bed of solid spheres — gas mixture[17]. This reference also includes equations which account for radiant transfer at higher temperatures.

$$k_e = k_f \left(\frac{1}{1-(1-\epsilon)^{1/3}} \right) \quad \ldots\ldots\ldots\ldots (10)$$

k_e is the conductivity of the bed mixture and k_f is the conductivity of the fluid.

The vessel wall and any exterior or interior insulation should be combined with the convection (free or forced) coefficient of the fluid surrounding the vessel to obtain the overall external heat transfer coefficient. This permits the advantage of external heat exchange to be studied.

Internal cooling could be installed as either coiled or straight tubes. This allows a coolant to be circulated more conveniently and reduce cooling time considerably. However, the fabrication cost can quickly become excessive.

The cooling time is calculated using standard approaches for conduction problems using the effective conductivity of the bed. If the cooling cycle time is critical, the designer should use detailed graphical or numerical methods.[5] A first approximation, which would at least be conservative, would use the Gurney-Lurie charts for a finite slab whose thickness equaled the longest bed distance between adjacent tubes or coils.

In some applications, raw feed gas is used to cool the bed to the desired adsorbing temperatures. This has the advantage of rapid cooling but, obviously, tends to presaturate the bed. The material adsorbed will add its latent heat to the bed, and in the adsorbing zone,

tends to nullify the sensible cooling effect of the gas.

If the latent heat effect is not too large, the designer can first estimate the cooling cycle time as equal to the regenerating cycle time. Using this time period, the amount of material deposited at the adsorbing temperature (step 1) can be calculated. The latent heat associated with this effectively lengthens the time by changing C_{ps} to C'_{ps} (Eq. 9) The calculation can be repeated a few times until the cooling time remains essentially unchanged.

The additional bed required because of this presaturation is indicated by the amount of material deposited during this cooling cycle. This can double the size of the required bed, and in the example would nearly triple it. This style of cooling is useful only where large changes in equilibrium constant occur for the temperature change induced by the regenerating cycle.

Design Of Adsorber Towers

There are typical characteristics for design of adsorption processes where an approach to complete removal of key component (s) is desired.

Shape: Vertical, cylindrical adsorber.

Flow: Downward, normal to bedding plane of sorbent.

Length/diameter: 4 minimum to 12 to 15 maximum depending on permissible pressure drop.

Allowable ΔP: 0.5 to 10 psi.

Velocity: Better designs based on free shell velocities of 0.5 ft per sec, although some may range to 1.0 ft per sec.

Adsorbent Capacity: Based on extended service life and ranges from 3 to 7% (pounds adsorbed per 100 lb adsorbent) with an average of 5%, regardless of initial capacity of new adsorbent.

Reactivation Flow: Both directions are used but reverse (upward) flow is preferred. Reactivation velocities usually range from 6 to 10 ft per min (free shell) depending on heat capacity of reactivation fluid; usually hot feed gas.

Reactivation Temp: This depends upon the adsorbing material, but usually ranges from 330 F minimum to about 500 F maximum.

Cooling: Freshly reactivated adsorbent is usually cooled to 100 to 120 F prior to return to service. Cooling procedures depend greatly upon process enviornment.

Liquid-Solid Contacting

Presumably this discussion applies equally well to heat transfer between liquids and solid beds. The parameters Y and Z may, however, lie below the values for which the approximate formulas upon which Fig. 2 is based are valid. In such a case, reference to the curves in Reference[8] must be made. In addition, other effects, particularly non-plug flow velocity effects may become more important. After regeneration, the displacement of hot liquid by a cold liquid can have very undesirable consequences. The larger thermal conductivity of the liquid may tend to broaden the temperature profile.

Application To Mass Transfer Cycle

The form of the equations for a mass transfer cycle is the same as Eq. 1 and 2.[20,15,12] The transfer coefficients can be estimated from Fig. 3 using $j_h = j_d$ [9,7]. Additional data for partition coefficients or absorption isotherms must be found and this is best obtained from manufacturers. Extensive data for molecular sieves is furnished by the Linde Company (270 Park Avenue, New York 17, New York) and for silica gel by the Davison Chemical Company (Baltimore 3, Maryland).

Considerable caution must be used for mass transfer applications, however, because pore diffusion may have a very important effect which is not normally included in data for mass transfer coefficients.

About the Author

Dr. O. K. Crosser, associate professor of chemical engineering at the University of Oklahoma, Norman, is particularly interested in heat transfer, development of mathematical descriptions of chemical engineering systems and computer applications. A registered professional engineer in Oklahoma, he holds BS and MS degrees from the University of Missouri and a PhD from Rice University. He is a member of the American Chemical Society, American Institute of Chemical Engineers, American Society for Engineering Education, Sigma Xi, National Society of Professional Engineers and American Association of University Professors.

Acknowledgment

The author is deeply indebted to Professors Mark Townsend and Laurence Reid for important help with adsorber design practice, and to Mr. Don Green for vital discussions of fixed bed-fluid heat transfer.

■

Part 1 Theory — by Dr. A. E. Dukler

Predicting Heat Transfer Coefficients For Film Flow

By using a newly-published theoretical analysis, you now can calculate heat transfer coefficients with accuracy for both laminar and turbulent film flow.

This accuracy will pay off in lower plant costs, since less excess surface will be required as a safety factor. In competitive bidding on turnkey process plants it can make the difference between success and failure of bid.

Film flow, which occurs widely in heat transfer equipment, is characterized by the movement of a thin layer of liquid along a solid boundary. It can take place under the influence of gravity, centrifugal force, interfacial shear caused by a fast moving gas stream or by many other devices.

Examples in HPI include film condensation in vertical tubes or in horizontal tubes at high vapor velocities, falling film evaporators, such as the one currently being used in the salt water conversion plant at Freeport, Texas: gas-liquid reactors or heaters operating in the annular flow regime; thermosyphon reboilers, and wiped film heat exchangers.

A theoretical analysis[2] published recently by the author treated in detail the problem of laminar and turbulent film flow. This article will introduce practical application of this theory. Working charts and examples will be given in the second part of the article, to appear in a subsequent issue.

Heat Transfer in Film Flows

Consider a single tube such as in Fig. 1A, in which liquid is flowing down the wall as a film. Over the length of the tube a number of different situations may exist. In condensation or vaporization the mass of each phase may change significantly along the axis. In other cases, such as in a wetted wall tower, the temperature of the liquid may change as it falls but the mass in each phase remains unchanged. Still other cases are possible.

It is important to note that the problem of predicting the heat transfer coefficient at any point in the tube is the same for any of these cases. Once the point or local coefficient can be determined the average coefficient can be evaluated by integrating (or adding up) the heat transfer at all points along the axis.

The objective, therefore, is to find the local coefficients and then to develop the relations by which the average coefficient can be obtained for different conditions along the tube axis.

Basic Equations for Point Coefficients

The problem, stated simply, is:

At any position along the axis of the tube, if the liquid and gas flow rates and properties are known, predict the heat transfer coefficient.

The basic equations which must be used to solve this problem are:

$$\tau = \frac{1}{g_C} (\mu_L + \varepsilon\rho_L) \frac{du}{dy} \quad . \quad . \quad . \quad (1)$$

$$Re_{Lx} = \frac{4\rho_L}{\mu_L} \int_0^m u dy \quad . \quad . \quad . \quad (2)$$

$$q = -(k_L + \varepsilon_H C p_L \rho_L) \frac{dt}{dy} \quad . \quad . \quad . \quad (3)$$

Fig. 2 illustrates the flow scheme. τ is the shear stress at any position, y, in the film. q is the heat flux at that same point, while t and u are the temperature and velocity respectively. ε and ε_H are the eddy viscosity and the eddy thermal conductivity. These terms are the turbulent

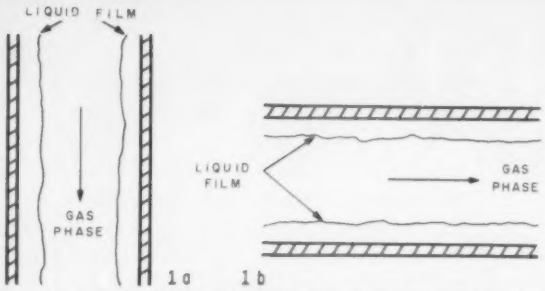

FIG. 1A. Film condensation or evaporation in vertical tubes. Thermosyphon reboiler operation would be represented by upward flow. FIG. 1B. Gas-liquid reactor or horizontal condenser with high vapor breakthrough.

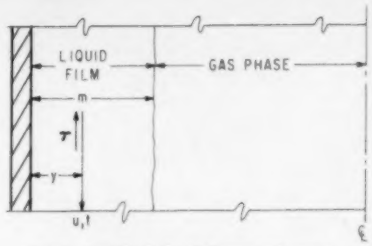

FIG. 2. Model of flow scheme.

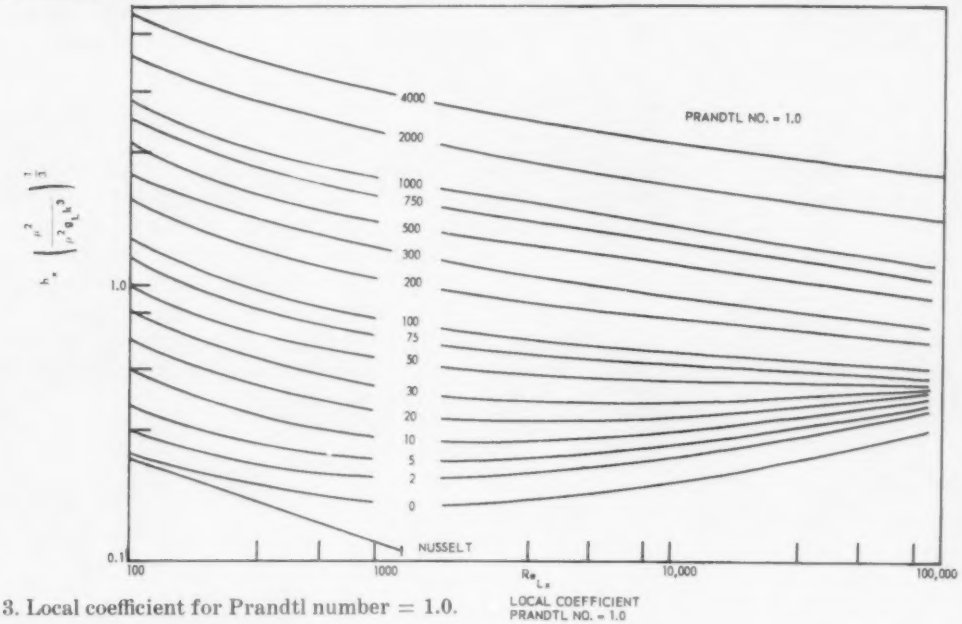

FIG. 3. Local coefficient for Prandtl number = 1.0.

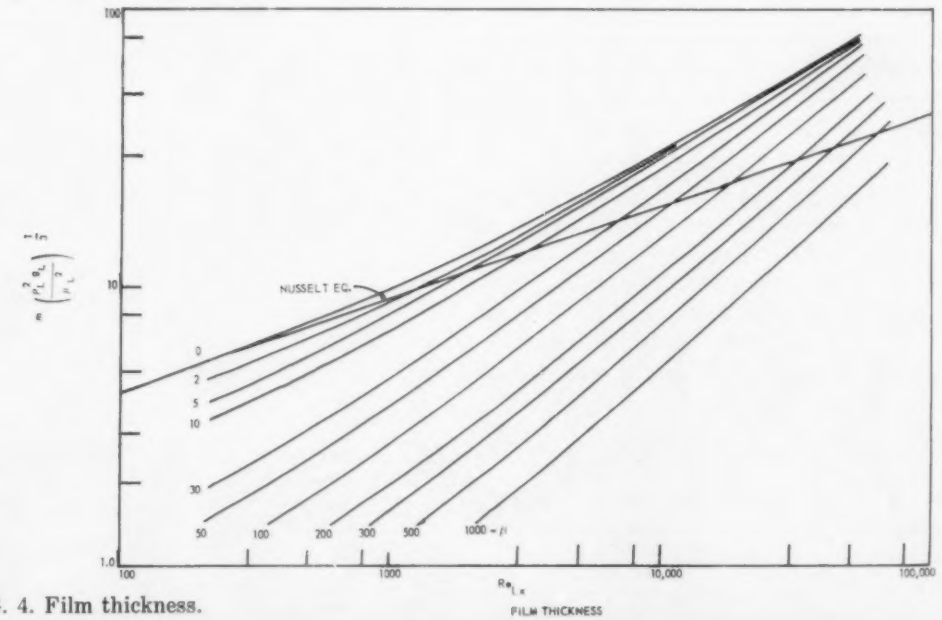

FIG. 4. Film thickness.

analogs to the molecular kinematic viscosity, μ/ρ, and thermal conductivity group, $k/C_p\rho$.

The heat transfer coefficient is determined by the solution of Eq. 3. Since the heat transfer coefficient, h, is defined by

$$h = \frac{q}{t_w - t_m} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

it is necessary only to find the temperature as a function of position, y, by solving Eq. 3; determine the difference between temperatures when y is zero (at the wall) and when y equals m (at the interface) and then divide this difference into the heat flux to obtain the transfer coefficient. To do this it is necessary to know two things: the correct expression for the eddy thermal conductivity, ε_H, and the film thickness, m.

Eddy Conductivity

The eddy conductivity is assumed equal to the eddy viscosity, as is frequently done when using the heat transfer analogy approach to problems such as this.

Thus $$\varepsilon = \varepsilon_H \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

These terms are evaluated using the equations of Deissler[1] for the region near the wall

$$\varepsilon = \varepsilon_H = n^2 u y \quad (1 - e^{\frac{-n^2 u y}{\mu/\rho}}) \quad . \quad . \quad . \quad (6)$$

and the equation of von Karman[3] in the flow field removed from the immediate vicinity of the wall

$$\varepsilon_H = \varepsilon = p \frac{(du/dy)^3}{(d^2u/d^2y)^2} \quad . \quad . \quad . \quad . \quad (7)$$

When Eq. 6 or 7 is substituted into Eq. 3, it becomes clear that the temperature at any point depends on the velocity, u, as well as the position variable, y, and the other terms in the equation

$$t = \phi(y, u, k_L, Cp_L, \rho_L) \quad . \quad . \quad . \quad . \quad (8)$$

Therefore, before Eq. 3 can be solved for temperature for use in Eq. 4, Eq. 1 must be solved for the velocity distribution and Eq. 2 must be solved for the film thickness, m. Solution of Eq. 1 also uses Eq. 6 and 7. It must further be recognized that the shear stress, τ, can be related to the two-phase pressure drop by the equation

$$\tau = \left(\frac{dP}{dL}\right)_{TP} \frac{r_0 - y}{2} \quad . \quad . \quad . \quad . \quad (9)$$

When Eq. 6 or 7 are substituted into Eq. 11 along with Eq. 9 it is seen that the velocity dependence can be expressed as follows:

$$u = \phi \left(y, \mu_L, \rho_L, r_o, \frac{dP}{dL}\right) \quad . \quad . \quad . \quad (10)$$

For any pressure drop and properties, the velocity is a unique function of position, y.

This set of differential equations was solved using a digital computer. Velocity distributions, film thicknesses, temperature distributions and local heat transfer coefficients were calculated.

Heat transfer coefficients were calculated for a series of Prandtl numbers from 0.1 to 10.0 and graphs prepared of the results.

A typical example of the heat transfer results is shown in Fig. 3. Theoretical film thickness results appear in Fig. 4. A complete set of working graphs will be included in Part 2.

Note that both of these graphs include a parameter, β. This term is simply a dimensionless grouping of variables which occurred in the solution of the differential equations and is defined as

$$\beta = \frac{(dP/dL)_{TP}\, r_0\, g_L^{1/3}}{2\, \rho_L^{1/3}\, \mu_L^{2/3}} \quad . \quad . \quad . \quad (11)$$

Either film thickness or heat transfer coefficient can be determined from values of the Reynolds number of the liquid Re_{Lx} and β. All terms in β are known except the two-phase pressure drop. Methods for calculating this quantity will be discussed later.

Results of this analysis have been shown to give excellent agreement with available experimental data.

Nomenclature

Cp_L = Specific heat of the liquid
$\left(\frac{dp}{dL}\right)_{T_p}$ = Two-phase pressure drop
g_L = Acceleration of gravity
h = Heat transfer coefficient
k_l = Thermal conductivity of liquid
m = Liquid film thickness
n = Numerical constant in Eq. 6
p = Numerical constant in Eq. 7
q = Heat flux
r_0 = Tube radius
Re_{Lx} = Local film Reynolds number
t = Temperature
u = Local velocity
y = Distance from the wall
β = Dimensionless interfacial friction defined in Eq. 11
ε = Eddy viscosity
ε_H = Eddy thermal conductivity
μ = Viscosity
ρ = Density
τ = Sheer stress

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■

Du Pont *Petroleum Chemicals* News

Number 109 in a series of bulletins for the Petroleum Industry JULY • AUGUST 1961

TWO MOVIES BARNSTORM THE COUNTRY

Oil companies tie in, to expand the demand

Now touring the country is "Down the Road," the CinemaScope featurette which co-stars the roads of America and the rich heritage they lead to.

Sponsored by Du Pont as part of the oil industry's travel-promotion program, this film is being met with applause by audiences everywhere.

In many localities, oil marketers have tied in with local showings.

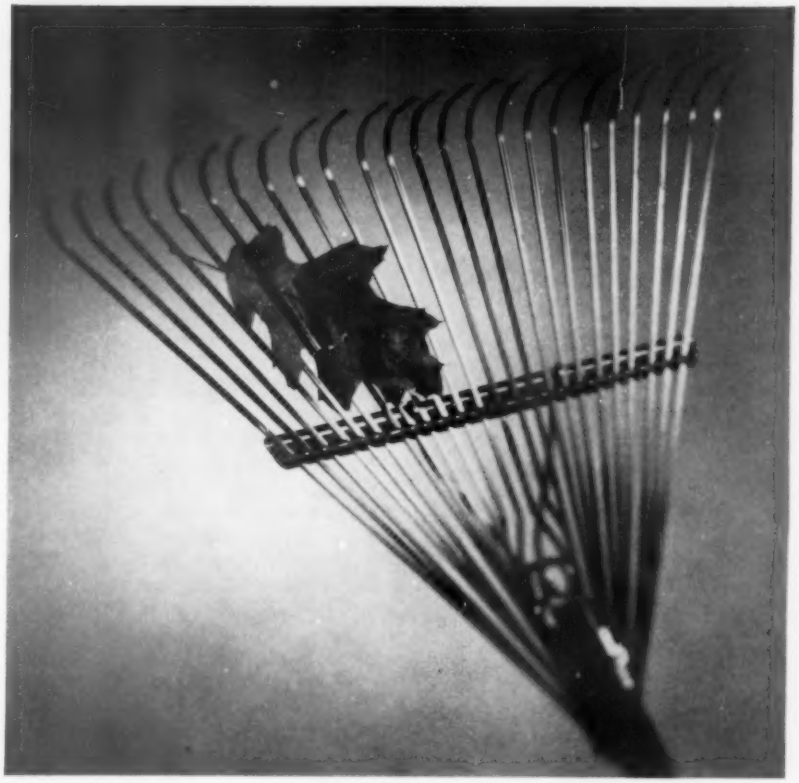
For example, in Albany, N. Y., service stations throughout the area blossomed forth with colorful posters promoting the movie. Efforts of several oil companies were carefully coordinated for this promotion by the Du Pont representative, who supplied the posters.

Your Du Pont representative can give you the playdates in your marketing area, if you are interested in running a similar promotion.

Also available is the 16-mm color movie, "Highway Holiday," a half-hour film which picks up the open-road theme of "Down the Road" and expands upon it. A number of oil companies are now using it as a part of their own travel-promotion programs.

Your Du Pont representative can arrange a showing of "Highway Holiday" for you, as well as supplying prints for showing to dealer meetings, civic groups, clubs, etc.

Both movies include scenes like this to stimulate interest in touring America.



How to sell a better fuel oil in the heating season ahead

Sometime between now and Labor Day, it can pay you to give a little extra attention to the stability of your fuel oil.

Sludge can be the source of many oil heater problems, customer complaints and loss of business. It clogs filters, plugs burner nozzles. It reduces capacity of your storage tanks (and your customers'), often creates an expensive cleanup problem.

But you can solve the sludge problem *before the heating season begins*, by adding a small quantity of Du Pont Fuel Oil Additive No. 2 to your fuel oil. Usually just 5 to 15 pounds of FOA-2 are enough to prevent sludging in 1,000 barrels of oil. Your costs are low.

FOA-2 is a solubilizer and dispersant. It prevents sludge accumulation, and can even disperse previously formed sludge.

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Refiners have stabilized millions of barrels of heating and fuel oils with FOA-2 since its introduction ten years ago. It continues to be one of the most profitable decisions you can make to safeguard the quality of your product.

Your Du Pont Petroleum Chemicals representative has the information you need to clear up the sludge problem *before* the fall heating season sets in.

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OVER ▶

Du Pont *Petroleum Chemicals* News

MID-CONTINENT TECHNICAL MANAGER

CHARLES B. MILLER is Technical Manager of the Du Pont Petroleum Chemicals Division, Mid-Continent Region, headquartered in Tulsa, Oklahoma.

Mr. Miller joined Du Pont in 1941 and was first assigned to Jackson Laboratory, one of Du Pont's basic research laboratories. He has been with the Petroleum Chemicals Division since 1952. Prior to his present assignment, he held the position of Mid-Continent Regional Laboratory Manager in Tulsa and Research Chemist at the main Petroleum Laboratory located at Carneys Point, New Jersey.

Mr. Miller and his laboratory staff make available to the oil industry the expanding technical services of Du Pont. Gasoline antiknocks and additives for petroleum products are his specialty. Wide experience in the laboratory and in the field enables him to assist refiners in the selection of the proper additive product to do a job.

Mr. Miller holds a Masters degree in Chemistry from the University of Delaware.

What's the score on motorists' buying habits?

The "Summary Report" of the Du Pont "Profile of the Motorist" survey is now available. This 40-page booklet contains a concise report of the results of the most extensive survey ever made of the American motoring public.

The new publication contains the survey's answers to questions such as how people react to price-wars, give-aways, trading stamps, regular vs. premium gasolines, TBA purchases, credit cards, vacation driving — and many other findings which explain the motorist and the market he represents.

The "Profile" survey is the fourth in the Du Pont series dealing with service station marketing. The "Summary Report" contains comparisons with the earlier surveys, to give marketing groups a picture of the trends in several areas of inquiry.

Your Petroleum Chemicals Division representative will be pleased to provide you with a copy of this new publication.

New developments in continuous gasoline blending discussed in talk

The advent of electronics has dramatically changed the position of in-line blending in the oil industry.

Until recently, most refineries had to make so many changes in field piping that they could not justify the expense.

It is no longer necessary to make such extensive field piping changes. With electronic control equipment and transmission of signals as digital pulses, gasoline components no longer need be piped to a central meter station adjacent to a control room.

Not only are piping costs much lower, but there are also new savings in the size, location and installation costs of the control room and control equipment.

B. G. Crane, Manager of Operations in Du Pont's Petroleum Chemicals Division, spoke on new in-line blending developments at the annual meeting of the W.P.R.A. If you would like a transcript of Mr. Crane's talk, contact your Du Pont representative.

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OVER

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Serial A-20427 117326 Printed in U.S.A.

by Dr. James R. Fair

Design of Direct-Contact Gas Coolers

Here for the first time are design methods for gas-liquid heat transfer in direct-contact gas cooling equipment.

Typical HPI applications are in reaction gas quenchers, compressor intercoolers, fractionator condensers, adiabatic humidifiers and feed gas desuperheaters.

Barometric condensers, feedwater heaters, steam desuperheaters and submerged combustion evaporators also fall in this category, however, design information on them is in the realm of proprietary art.

In their simplest form, direct-contact heat exchangers consist of open vessels where the process stream and coolant are commingled directly. There is no heat flow resistance of a separating wall, nor complexity due to arranging this wall for maximizing the heat transfer surface.

Their attractiveness stems from their potential economy and simplicity, plus their ability to handle a wide variety of fluids and solids — often under conditions that would cause excessive fouling, corrosion or thermal stressing in conventional tubular equipment.

This article is directed to the process design engineer. It reviews present direct-contact practice, summarizes available performance data, suggests tentative design methods and proposes areas for further engineering research and development.

In using the material, the reader should note with caution the scope of each correlation and temper it as needed to suit the specific design situation at hand.

Basic Equations

A typical direct-contact cooler is shown schematically in Fig. 1, together with basic nomenclature. The hot gas stream, which may contain condensibles, enters at the bottom in counterflow to the coolant liquid. The designer must obtain the total volume required for the specified duty:

$$V_T = \int_0^{V_T} dV = \int_0^{Q_T} \frac{dQ}{Ua\,(t_G - t_L)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

and for effective average values.

$$V_T = \frac{Q_T}{Ua\Delta t_m} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where the volumetric coefficient Ua is carried as a product. This is the usual case where interfacial transfer area cannot be defined.

The usual heat exchanger design problem is how to determine point and over all values for the rate coefficient Ua and the driving force Δt. This article deals with the problem according to character of gas cooling: without mass transfer, with dehumidification and with humidification.

Gas Cooling Without Mass Transfer

There are a few industrial cases where a non-volatile liquid cools a dry, hot gas. In other cases local mass transfer occurs, yet with the overall result of gas cooling without mass transfer. The transfer process is represented by the expressions

$$Q_T = Ua \cdot V_T \cdot (t_G - t_L)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3a)$$
$$= h_G a \cdot V_T \cdot (t_G - t_i)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3b)$$
$$= h_L a \cdot V_T \cdot (t_i - t_L)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3c)$$

with, of course, equivalent differential expressions applying to point conditions.

The overall coefficient is represented by the familiar expression

$$\frac{1}{Ua} = \frac{1}{h_G a} + \frac{1}{h_L a} + \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Only rarely is it feasible to obtain point values of rate coefficients and driving force. Depending upon the equipment involved, flow

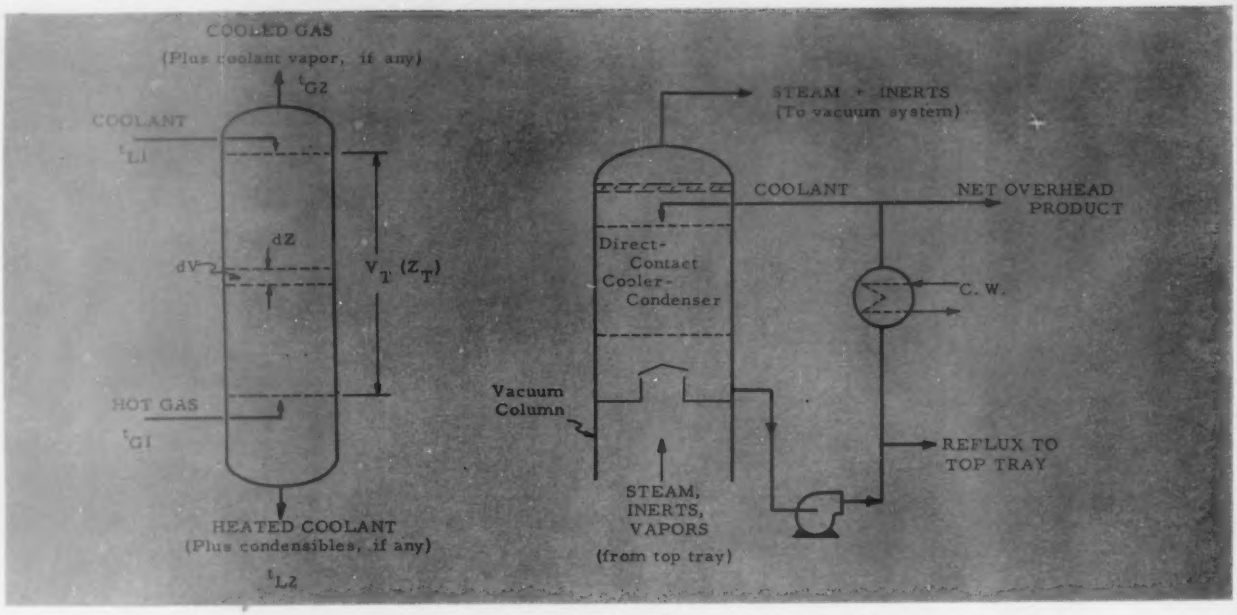

FIG. 1. Direct-Contact cooler.

FIG. 2. Typical cooler-condenser (vacuum steam fractionator condenser).

patterns of the fluid streams are complex, and accurate measurements of heat transferred and temperature potential are impossible to obtain. In industrial practice, stepwise calculations to obtain a true average driving force usually cannot be justified.

In this article the logarithmic mean temperature difference, based on terminal conditions, is used in full knowledge that it does not represent accurately the true physical picture. The logarithmic average permits rapid calculations, and its use can be justified if experimental rate data covering broad conditions can be correlated when it is used. Such justification is presented later.

Direct cooler-condensers are often used in process plants. Frequently the coolant is the material condensed. A typical application is shown in Fig. 2 where reflux is condensed in a vacuum steam distillation column. (For such an application, pressure drop can be quite low.)

If condensibles in the gas stream are considered as an "average" diffusing component, A, mass transfer to the interface is

$$N_A = k_G a \cdot V_T \cdot (p_G - p_i)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and overall heat transfer is

$$Q_T = Q_G + Q_C = Q_G + N_A \lambda_A \quad . \quad . \quad . \quad . \quad . \quad (6)$$

also,

$$Q_T = Ua \cdot V_T \cdot (t_G - t_L)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad (7a)$$

$$= \alpha h_G a \cdot V_T \cdot (t_G - t_i)_M + N_A \lambda_A \quad . \quad . \quad . \quad (7b)$$

$$= h_L a \cdot V_T \cdot (t_i - t_L)_M \quad . \quad . \quad . \quad . \quad (7c)$$

The duty for sensible cooling of the gas only is

$$Q_G = \alpha h_G a \cdot V_T \cdot (t_G - t_i)_M \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and the overall transfer coefficient is represented by

$$\frac{1}{Ua} = \frac{1}{\alpha h_G a} + \frac{1}{h_L a} - \frac{N_A \lambda_A}{Q_T \alpha h_G a} \quad . \quad . \quad . \quad . \quad (9a)$$

$$= \frac{1}{h_L a} + \frac{1}{\alpha h_G a} \cdot \frac{Q_G}{Q_T} \quad . \quad . \quad . \quad . \quad (9b)$$

In Eq. 7-9 the multiplier α is the "Ackerman correction" factor [21] which is defined as follows:

$$\alpha = \frac{C_o}{1 - e^{-C_o}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

$$\text{where } C_o = \frac{N_A M_A C_A}{V_T h_G a} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

For dehumidification, N_A is positive and α is greater than unity; hence use of the "dry" coefficient (Eq. 3b) gives somewhat conservative results. For many process applications, it may be assumed that $\alpha = 1.0$, particularly in view of the assumptions made in evaluating temperature driving force.

The comparison between Eq. 4 (no mass transfer) and Eq. 9b is noteworthy. The ratio Q_G/Q_T is known from the overall heat balance and is used to adjust the gas phase coefficient. In many cases there is negligible resistance to heat transfer in the liquid phase (i.e., $t_i \rightarrow t_L$ and $h_L a \rightarrow \infty$); for these cases

$$Ua = \alpha h_G a \frac{Q_T}{Q_G} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

and

$$V_T = \frac{Q_T}{\alpha h_G a (\Delta t_M)(Q_T/Q_G)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

$$= \frac{Q_G}{\alpha h_G a \, \Delta t_M}$$

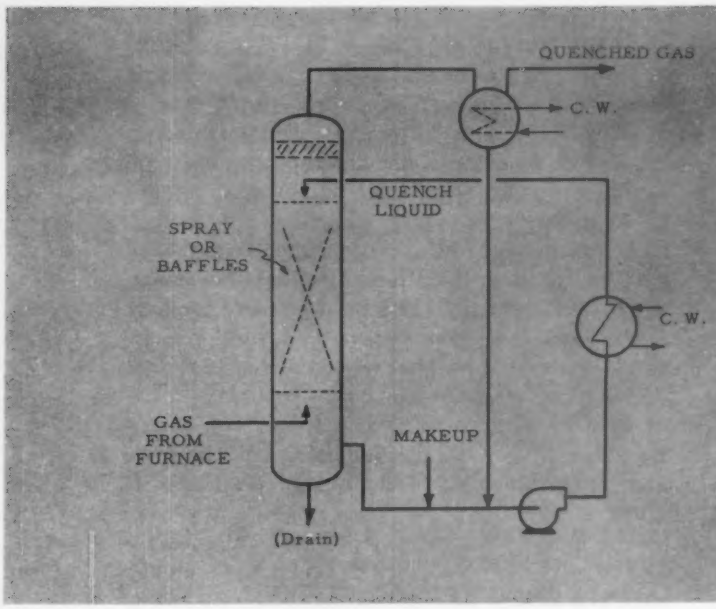

FIG. 3. Typical cooler-humidifier (quenching pyrolysis gases).

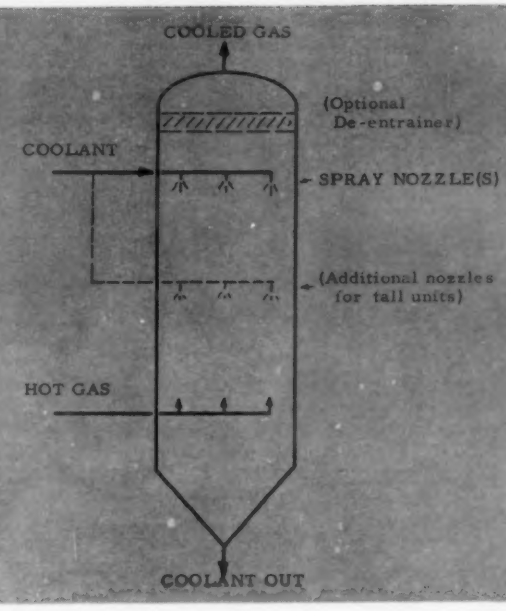

FIG. 4. Typical spray cooler.

Eq. 13 is often used for sizing cooler-condensers when the condensate and coolant are the same.

Gas Cooling With Humidification

When very hot gases are cooled by direct contact, it often is desirable to vaporize coolant and permit it to be carried overhead for later condensation. A typical application, pyrolysis gas quenching, is shown in Fig. 3.

Considering vaporization of part of the coolant, mass transfer away from the interface is represented by

$$N_A = k_G a \cdot V_T \cdot ((p_i - p_G)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

and overall heat transfer is

$$Q_T = Q_L + Q_V = Q_L + N_A \lambda_A \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Also,

$$Q_T = Ua \cdot V_T \cdot (t_G - t_L)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad (16a)$$

$$= \alpha h_G a \cdot V_T \cdot (t_G - t_i)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad (16b)$$

$$= h_L a \cdot V_T \cdot (t_i - t_L)_M + N_A \lambda_A \quad . \quad . \quad . \quad . \quad (16c)$$

The duty for sensible heating of the liquid is

$$Q_L = h_L a \cdot V_T \cdot (t_i - t_L)_M \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

The overall coefficient is represented by

$$\frac{1}{Ua} = \frac{1}{\alpha h_G a} + \frac{1}{h_L a} - \frac{N_A \lambda_A}{Q_T h_L a} \quad . \quad . \quad . \quad . \quad (18a)$$

$$= \frac{1}{\alpha h_G a} + \frac{1}{h_L a} \cdot \frac{Q_L}{Q_T} \quad . \quad . \quad . \quad . \quad . \quad (18b)$$

For humidification, the multiplier α is unity or less (N_A is negative), since mass transfer and heat transfer are in opposite directions.

Frequently, operation of the cooler approaches that of an adiabatic humidifier, in which case $t_i \rightarrow t_L$, $Q_L \rightarrow 0$, and $h_L a \rightarrow \infty$. Then,

$$Ua = \alpha h_G a \quad . \quad . \quad . \quad . \quad . \quad (19)$$

and, since $Q_T = Q_G$,

$$V_T = \frac{Q_G}{\alpha h_G a \, \Delta t_M} \quad . \quad . \quad . \quad (20)$$

The similarity of Eq. 13 and 20 should be noted. For those cases where heat transfer resistance in the liquid phase can be neglected, the direct-contact cooler may be sized on the basis of gas cooling duty only.

Process direct-contact coolers may be classified roughly as spray, plate and packed coolers. Within each category there are wide variations in equipment design and geometry, and heat transfer rate data is thus subject to the same vagaries as the corresponding mass transfer data.

Rate Data For Spray Coolers

A simple yet effective type of direct-contact cooler consists of an empty chamber into which coolant is introduced in the form of a fine spray. Gas and coolant often are in counter flow, but crossflow and concurrent flow have also been used. Dispersion of liquid is usually obtained from one or more pressure nozzles of the solid-cone type. The spray contains a large interfacial area in the vicinity of the nozzle, but at distant points the area is decreased due to drop coalescence and collection of liquid on the

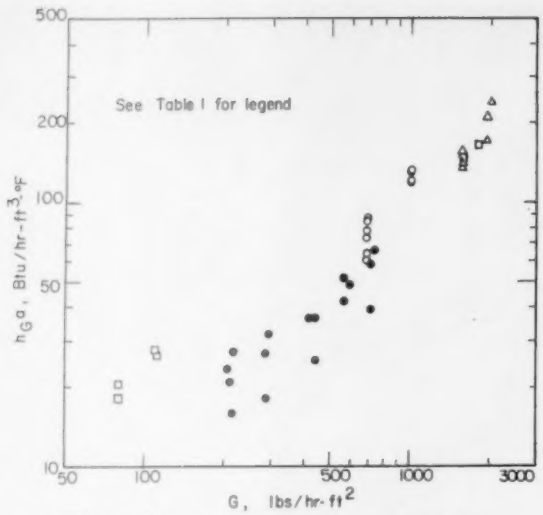

FIG. 5. Spray cooler heat transfer data.

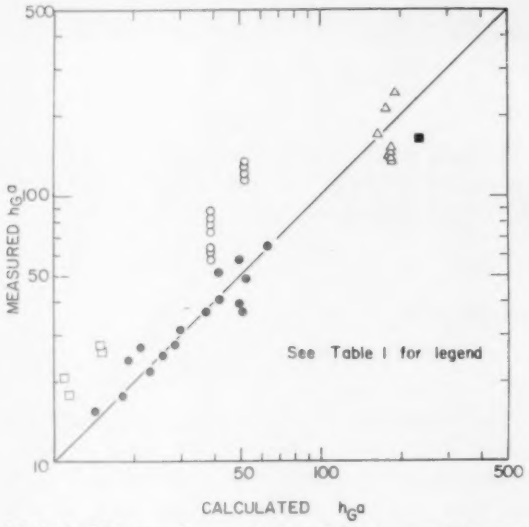

FIG. 6. Measured vs calculated heat transfer rate, spray coolers.

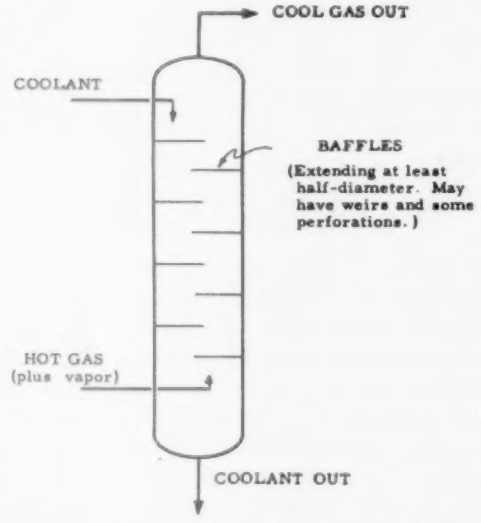

FIG. 7. Typical plate cooler (segmental baffles).

chamber walls. A typical process cooler is shown in Fig. 4.

Spray cooler data applicable to process design is shown in Fig. 5. Sources and other details are given in Table 1. The plotted data is uncorrelated, and has been calculated on the basis of Eq. 3, 13 and 20 (negligible liquid phase resistance).

Additional rate information, not readily convertible to $h_G a$ data, is found in the publications of Coons [4], Whitman and Keats [23], Boelter and Hori [2] and Niederman et al [15]. Several papers (e.g., Brown[2]) show that when condensing duty only is involved, volumetric transfer rates of several thousand Btu per hr per cu ft may be obtained — a strong indication of the lowered importance of liquid phase resistance in spray coolers.

The data of Fig. 5 may be better aligned by considering two additional variables: liquid rate and height between nozzles. The resulting correlating equation is

$$h_G a = \frac{0.043}{Z_T^{0.5}} G^{0.8} L^{0.4} \quad . \quad . \quad . \quad . \quad (21)$$

where Z_T is the effective height of the chamber (or height between nozzles if more than one set is used), L is the entering liquid rate and G is the gas rate not including vapor removed or added.

Eq. 21 was developed as follows: The height correction was obtained from the papers of Pigford and Pyler [18], Boelter and Hori [2] and the author's tests at various spray heights. The exponent on gas rate was based on the droplet

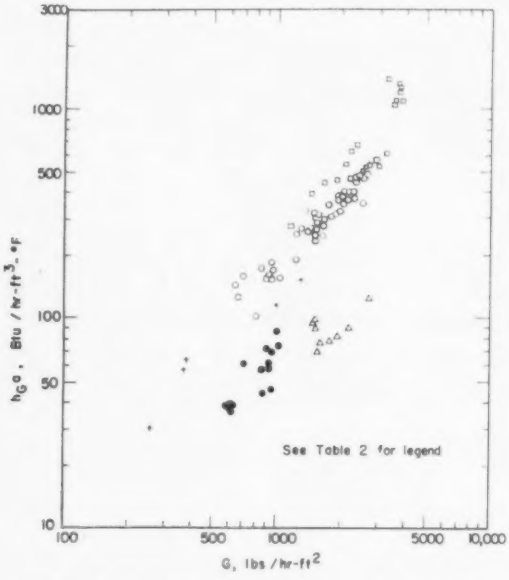

FIG. 8. Plate cooler heat transfer data.

transfer work of Froessling [6] and Marshall and Ranz [13], taking into consideration gas-liquid relative velocities and probable effective average droplet diameters. The exponent on the liquid rate was obtained directly from the data of Fig. 5.

Fig. 6 shows a comparison of measured and calculated h_Ga values. The organics-steam cooling data lies above the correlation line, and this is partly because the data were obtained under adiabatic humidification conditions and thus are true h_Ga values. Otherwise, Eq. 21 represents the data reasonably well. The need for more work in this area is apparent.

Rate Data For Plate Coolers

Plate coolers take the usual form of commercial fractionating columns. Trays with liquid crossflow and down comers are used to some extent, but more often simple baffle trays (segmental or disc-and-doughnut) are preferable. Hot gas contacts coolant either by bubbling through it on a tray or by passing through it showering from one baffle to the next. The column diameter is calculated by the same procedures used for distillation or absorption columns. A typical design is shown in Fig. 7.

Plate cooler data applicable to process design is shown in Fig. 8. Sources and other details are given in Table 2. The air-water data[8,22] is true h_Ga data, and for the pyrolysis quench units liquid-phase resistance is likely to be small. The data using oil coolant[9,17] undoubtedly includes a significant liquid-phase resistance.

TABLE 1. Spray Cooler Data.

Service	Cooling H_2–C_4 mixture[17]	Cooling air[18]	Cooling organics-steam mixture*	Quenching pyrolysis gas*
Entering gas, F	760–860	145–155	315–390	1000–1200
Exit gas, F	265–342	82–107	210–225	100; 350
Mass transfer	H	D	H	None
Coolant	Oil	Water	Water	Water, Oil
No. nozzles	15	6	1	1
L-range, lb/hr-ft²	9000–20,000	290–980	580–650	4000–4500 30,000
G-range, lb/hr-ft²	1570–2000	200–750	680–1000	80–110; 1800
Diameter, ft	6.0	2.6	3.0	3.0; 2.5
Height, ft	17	4.3	7.0	13; 20
Symbol (Fig. 5)	Δ	●	○	□ ■

Notes: H = Humidification, D = Dehumidification
* = Unpublished data

TABLE 2. Plate Cooler Data.

Service	Cooling H_2–C_4 mixture[17]	Cooling air[8]	Cooling air[22]	Cooling cat. cracker gas[9]	Quenching pyrolysis gas*
Entering gas, F	280-310	~85-95	150-230	860-930	800-1200
Exit gas, F	140-215	~70-80	90-120	470-610	100-150
Mass transfer	D	H	H	D	D
Coolant	Oil	Water	Water	Oil	Water
L-range, lb/hr-ft²	3000-6000	1300-9000	2700-7700	2300-4200	4000-20,000
G-range, lb/hr-ft²	575-1000	1100-4000	650-3000	1500-2700	250-1300
Type plate	DD	SB	PP	DD	SB
Plate spacing, in.	30	18	23	30	24
Diameter, ft	10	0.5 x 1.5	0.5	16	4-8
Symbol (Fig. 8)	●	□	○	Δ	+

Notes: D = Dehumidification, H = Humidification
DD = Disc and Doughnut Baffles
SB = Segmental Baffles
PP = Perforated Plates
* = Unpublished data

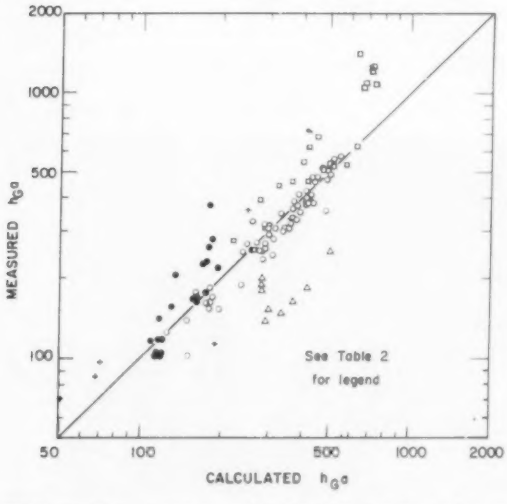

FIG. 9. Measured vs calculated heat transfer rate, plate coolers.

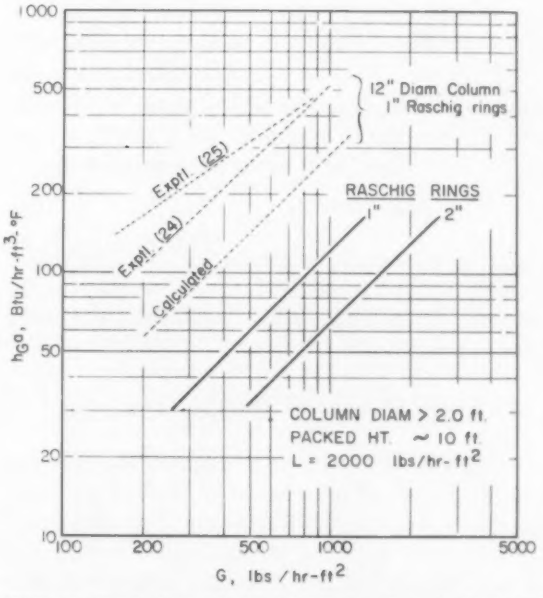

FIG. 10. Packed cooler heat transfer data (calculated for producer gas water).

For air-water, h_L has been found to be two to three times h_Ga [8,22]; for oil systems it is estimated to be about equal to h_Ga.

The air-water data may be correlated by the simple expression

$$h_Ga = 0.19G \quad . \quad . \quad . \quad . \quad . \quad (22)$$

The other data are then corrected to h_Ga values by means of the relations

$$h_La = h_Ga \text{ (oil coolant)}$$
$$h_La = 2h_Ga \text{ (water coolant)}$$

and Eq. 9b. The correlation plot is shown in Fig. 9. Notice the catalytic cracked gas data falls below the correlation line; the particular application involves a heavy coolant oil slurry and it is likely liquid-phase resistance is high.

There is additional support for Eq. 22, useful when it is extended outside the range of experimental data. This involves the concept of "temperature efficiency," introduced many years ago[3], but not generally used. This efficiency is defined as follows:

$$E_T = \frac{t_{G_1} - t_{G_2}}{t_{G_1} - t_L} \quad . \quad . \quad . \quad . \quad . \quad (23)$$

For binary systems this efficiency is approximately equal numerically to the Murphree tray efficiency, E_{MV}, for mass transfer[3,16]. If it is assumed the tray liquid is well mixed (t_L = const.) and the liquid-phase heat transfer resistance is low,

$$h_Ga = \frac{GC_G}{h_{TS}} \ln \frac{t_{G_1} - t_L}{t_{G_2} - t_L} \quad . \quad . \quad (24)$$

Combining Eq. 23 and 24,

$$h_Ga = \frac{2.303GC_G}{h_{TS}} \log \frac{1}{1 - E_T} \quad . \quad (25)$$

Applying this equation to the data of Stewart and Huntington [22], where $h_{TS} \sim 2.0$ and $C_G \sim 0.26$, and taking $E_T = 0.65$ for a perforated tray,

$$h_Ga = 0.136G \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (26)$$

which is reasonably close to Eq. 22. Additional work is needed to define better the relationship between E_T and E_{MV}. Also, E_{MV} values for baffle towers are needed.

Rate Data for Packed Coolers

Problems of designing packed coolers are similar to those of designing packed columns for mass transfer. Interfacial area and heat transfer rate must be determined as a function of gas and liquid flow, system properties, column geometry and packing characteristics. Most attention has been given to the mass transfer aspect, although completely reliable design methods have not been developed. Because of the relatively little attention given to heat transfer, particularly in the way of commercial-scale experimental investigations, the safest approach to design appears to be through mass transfer — heat transfer analogies.

Recently the author and co-workers published empirical methods for sizing packed columns for mass transfer[5]. The methods are based on a comprehensive analysis of literature data and are believed to be the most reliable generalized methods presently available. Raschig ring and Berl saddle packings are covered, with extension to other packings possible by direct comparison.

With mass transfer as a basis, the familiar analogy is used:

$$\frac{k_Ga P}{G_M} Sc_G^{2/3} = \frac{h_Ga}{C_G' G_M} Pr_G^{2/3} \quad . \quad . \quad (27)$$

where it is assumed the interfacial area for heat transfer equals that for mass transfer. A similar analogy may be written for the liquid phase.

The heights of transfer units H_G and H_L for the two phases may be defined as

$$H_G = \frac{G_M}{k_Ga P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (28)$$

$$H_L = \frac{L}{k_L a \rho_L} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (29)$$

Combining Eq. 27 and 28,

$$h_Ga = \left(\frac{Sc_G}{Pr_G}\right)^{2/3} \frac{C_GG}{H_G} \quad . \quad . \quad . \quad . \quad . \quad (30)$$

and, similarly,

$$h_La = \left(\frac{Sc_l}{Pr_L}\right)^{2/3} \frac{C_LL}{H_L} \quad . \quad . \quad . \quad . \quad . \quad (31)$$

TABLE 3. Packed Cooler Design Coefficients.

	Raschig rings		Berl saddles	
	1 in.	2 in.	1 in.	1½ in.
Gas phase transfer				
Exponent "m"	0.6	0.6	0.5	0.5
Exponent "n"	1.24	1.24	1.11	1.11
Parameter ψ:				
40% flood	110	210	60	80
60% flood	105	210	60	80
80% flood	80	(210)	(60)	(80)
Liquid phase transfer				
Parameter ϕ:				
L = 500	0.045	0.059	0.029	0.032
L = 1000	0.048	0.065	0.037	0.040
L = 5000	0.048	0.090	0.068	0.068
L = 10,000	0.082	0.11	0.090	0.090
Parameter C_F:				
< 50% flood	1.0	1.0	1.0	1.0
60% flood	0.90	0.90	0.90	0.90
80% flood	0.60	0.60	0.60	0.60

Note: Values in parentheses are extrapolated. See Ref. 5.

The exponent on the Schmidt-Prandtl number ratio is probably closer to one-half, but for the present purposes further refinement is not justified.

Values of H_G and H_L are obtained from expressions[5]:

$$H_G = \frac{\psi Sc_G^{0.5}}{(Lf_1f_2f_3)^m}\left(\frac{d}{12}\right)^n\left(\frac{Z_T}{10}\right)^{1/3} \quad . \quad . \quad . \quad . \quad . \quad . \quad (32)$$

$$H_L = \phi\, Sc_L^{0.5}\, C_F (Z_T/10)^{0.15} \quad . \quad . \quad . \quad . \quad . \quad (33)$$

where

$$f_1 = (\mu_L/2.42)^{0.16} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

$$f_2 = (62.4/\rho_L)^{1.25} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (35)$$

$$f_3 = (72.8/\sigma)^{0.8} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (36)$$

and the values of ψ, ϕ, C_F, m and n are obtained from Table 3 or from the original reference[5]. The value of the column diameter, d, in Eq. 32 should be limited to 24 in. maximum, even if the actual column diameter is larger. Analysis of commercial scale packed coolers indicates that with good initial liquid distribution, the column diameter effect disappears above 24 in.

Fig. 10 shows $h_G a$ values calculated for large commercial towers, and for the typical case of cooling producer gas ($C_G = 0.27$) with water. Also included on Fig. 10 are calculated and experimental [24,25] data for a 12-in. column size; it can be seen that the calculated data are conservative.

Further comparison with laboratory work using air and non-volatile oil[10,19], and with industrial installations of the author's knowledge, confirms that Eq. 32-36 give conservative results on an overall basis. There is great need for experimental data on large-scale heat transfer installations.

Additional data for use with grid-packed columns may be obtained from the publications of Furnas and Newton[7], Johnstone and Singh[11], Rosebaugh [20] and Molstad et al [14]. In general, rate coefficients for grid-packing are lower than those for Raschig rings and Berl saddles.

Summary of Design Recommendations

For vertical direct-contact gas coolers, vessel diameter should be obtained from the usual correlations for liquid-vapor contactors. For counter-flow, the upper limit of gas rate is based on excessive entrainment, and in some cases it is desirable to specify an entrainment collector above the liquid distributor. Another general consideration is that coolant be distributed uniformly to the entire cross section (for plate columns this is taken care of automatically).

The temperature driving force may usually be taken as the logarithmic mean. Certain cases may warrant dividing the cooler into, say, two zones, each with a heat balance and rate calculation. The Ackerman correction (Eq. 10) should also be considered when volumetric mass transfer is likely to be high.

For spray coolers, $h_G a$ should be calculated by Eq. 21. Liquid resistance may usually be neglected. Solid-cone nozzles should be arranged for good coverage of the tower cross-section, and if the tower is tall, separate sets of nozzles should be located about every 6 to 8 feet.

For plate coolers, $h_G a$ should usually be calculated by Eq. 22. Values of $h_L a$ should be based on coolant properties, and generally range from $h_L a - h_G a$ for oil to $h_L a - 2\, h_G a$ for water. If good E_{MV} data is available, Ua and $h_G a$ values may be estimated from Eq. 23 and 25, respectively.

For packed coolers, $h_G a$ and $h_L a$ values should be calculated by Eq. 30 and 31, based on the

About The Author

Dr. James R. Fair, section head in the engineering research section of Monsanto Chemical Co., lists direct-contact heat transfer among his principal engineering interests. For the past five years he has been in charge of the engineering research program at Monsanto's central research facility, recently moved to St. Louis, Mo., from Dayton, Ohio. Dr. Fair holds three chemical engineering degrees — a BS from Georgia Institute of Technology, MS from University of Michigan and PhD from University of Texas.

heat transfer-mass transfer analogy. The calculated values are conservative for large tower sizes.

These methods are tentative and in most cases conservative. There is great need for plant data on direct-contact heat transfer, and as such data is accumulated it may be advisable to make appropriate adjustments in the methods.

Nomenclature

- a = interfacial area, ft²/ft³.
- C_A = molar heat capacity for diffusing component, Btu/lb mole – F.
- C_F = flooding factor, Eq. 33.
- C_G = heat capacity of gas, Btu/lb F. C_G' = molar heat capacity of gas, Btu/lb mole – F.
- C_L = heat capacity of liquid, Btu/lb – F.
- C_o = coefficient in Ackerman factor, Eq. 11.
- d = column diameter, in.
- D = diffusion coefficient, ft²/hr. D_G for gas phase, D_L for liquid phase.
- E_{MV} = Murphree tray efficiency.
- E_T = Temperature efficiency, Eq. 23.
- f = Factor in Eq. 32. Factors f_1, f_2 and f_3 are defined in Eq. 34-36.
- G = Gas mass velocity, lb/hr – ft². G_M = lb moles/hr – ft².
- $h_G a$ = volumetric heat transfer coefficient, gas phase, Btu/hr – ft³ – F.
- $h_L a$ = volumetric heat transfer coefficient, liquid phase, Btu/hr – ft³ – F.
- h_{TS} = tray spacing, ft.
- H_G = height of gas phase transfer unit, ft.
- H_L = height of liquid phase transfer unit, ft.
- $k_G a$ = volumetric mass transfer coefficient, gas phase, lb – moles/hr – ft³ – atm.
- $k_L a$ = volumetric mass transfer coefficient, liquid phase, lb – moles/hr – ft³ (lb moles/ft³).
- L = liquid mass velocity, lb/hr – ft². L_M = lb moles/hr – ft².
- m = exponent in Eq. 32.
- M_A = molecular weight of diffusing component A.
- n = exponent in Eq. 32.
- N_A = rate of diffusion of component A, lb moles/hr.
- p = partial pressure of component A, atm. p = pressure in bulk gas. p_i = pressure at interface.
- P = total pressure, atm.
- Pr = Prandtl number, C_μ/k. Pr_G for gas phase, Pr_L for liquid phase.
- Q = Heat transfer rate, Btu/hr. Q_C = rate due to condensation. Q_G = rate due to sensible cooling of gas. Q_L = rate due to sensible heating of liquid. Q_T = total rate. Q_V = rate due to vaporization of liquid.
- Sc = Schmidt number, $\mu/\rho D$. Sc_G for gas phase, Sc_L for liquid phase.
- t = temperature, F. t_L = liquid temperature. t_G = gas temperature. t_{G_1} = gas temperature entering. t_{G_2} = gas temperature leaving. t_i = interface temperature.
- Ua = overall volumetric heat transfer coefficient, Btu/hr – ft³ – F.
- V = heat transfer volume, ft³. V_T = total volume in cooler.
- Z = height, ft. Z_T = height between spray headers (spray coolers) or liquid-vapor redistributors (packed coolers).
- α = Ackerman correction factor, Eq. 10.
- λ_A = heat of vaporization of component A, Btu/lb – mole.
- μ = viscosity, lb/ft – hr. μ_G for gas, μ_L for liquid.
- ρ = density, lb/ft³. ρ_G for gas, ρ_L for liquid.
- σ = surface tension, dynes/cm.
- ψ = coefficient in Eq. 32.
- ϕ = coefficient in Eq. 33.

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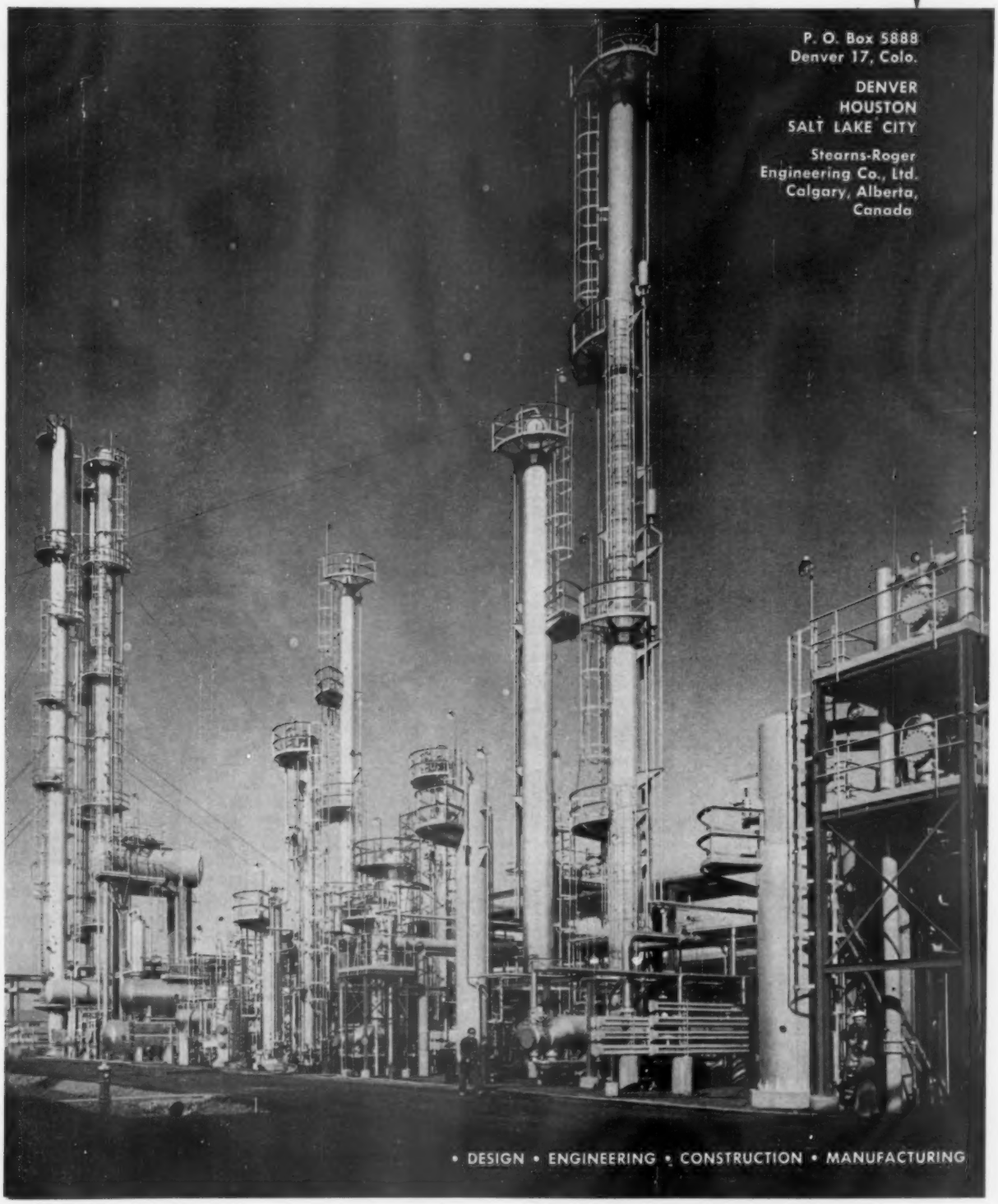

HPI Equipment

Centrifugal Contactors

Centrifugal contactors, solvent extractors, chemical reactors, separators and clarifiers are among products discussed in 24-page Brochure P-100. The operating principle of these countercurrent, liquid-liquid and vapor-liquid machines is described with the help of illustrations and diagrams. *Podbielniak, Inc., Division of Dresser Industries, Inc.*

Circle number (41) on reply card.

Cradle-Mounted Pumps

Cradle-mounted, centrifugal pumps for process service are treated in new product bulletin from Ingersoll-Rand. These pumps can be used on almost any service requiring a pump to handle both corrosive and non-corrosive liquids. Three models cover the line, ranging in size from ¼ through 50 hp. Delivery range is to 1000 gal per min, and total head available ranges to 240 ft. *Ingersoll-Rand Co.*

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Evaporator-Contactors

Vacuum flash evaporators are detailed in a new bulletin from Stratford Engineering. Depending on their application, the units can be used either as evaporators or as vapor-liquid contactors. When employed as an evaporator, the machine is designed to remove small percentages of dissolved gases or low boiling point liquids from higher boiling point liquids. Typical uses are "brightening" lube oils, dehydration of transformer oils and jet fuels, dehazing of furnace oils and degassification and deaeration of various products. When employed as a contactor, typical uses are the deodorization of waxes by steam stripping under vacuum, the sulfonation of oils with vaporized sulfur trioxide under pressure, the partial oxidation of hydrocarbons and gas stripping. *Stratford Engineering Corp.*

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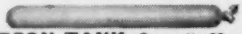

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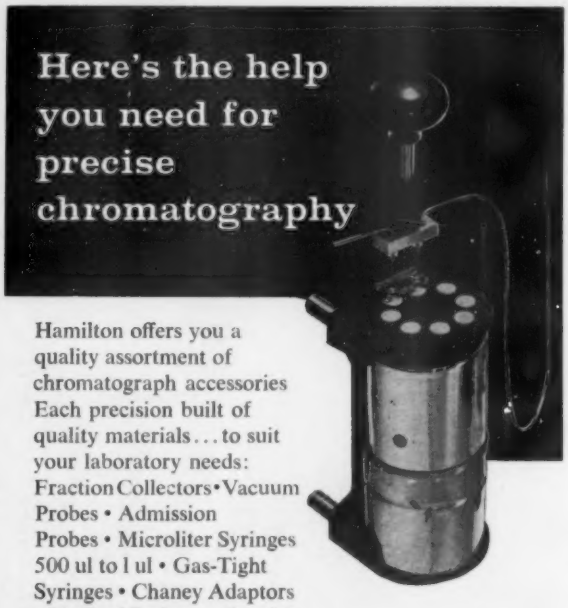

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How to Supervise

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Interchangeable Pump Parts

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Iron Mike Fittings

Iron Mike, described fully in Bulletin 651, fills the bill as a low cost yet reusable fitting for high pressure hose assemblies. Designed for use with Aeroquip 1509 multiple wire braid hose, Iron Mike fittings come in sizes to fit hose sizes ranging from ¼ to 2 in. This hose is suitable for operation in temperatures ranging from −40 to +200 F, and for use with hydraulic fluids, crude oil, fuel and lubricating oils, gasoline and air. *Aeroquip Corp.*

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Flow Switch-Alarm

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Karbate impervious graphite counterflow block heat exchanger, Type CFB, is subject of an 8-page illustrated catalog. These exchang-

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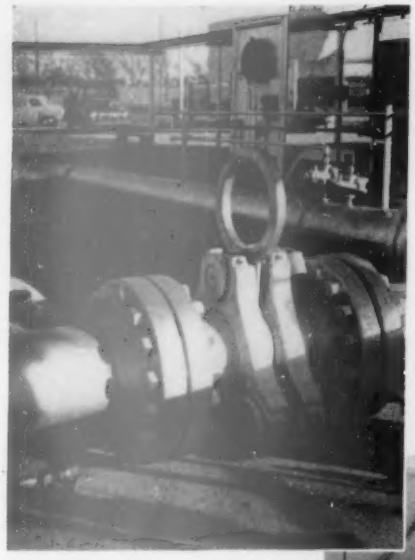

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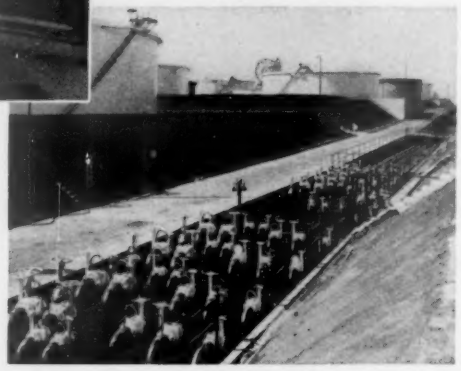

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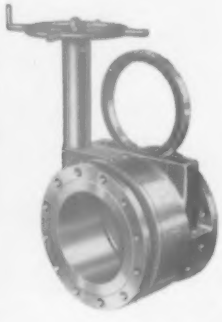

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How to Buy Ball Valves

How to buy a ball valve is subject of Bulletin HTB-261, which enumerates eight important features a buyer should look for in a ball valve. Gives specifications of Series 701 top entry 150-lb ASA flanged Flo-Ball valve. *Hydromatics, Inc.*

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C-100 two-stage Spiraxial compressors will deliver up to 3000 cu ft per min of oil-free air at 100 psig for processing, agitation, homogenization, oxidation, test facilities and other applications requiring high purity air. *Roots-Connersville Blower, Division of Dresser Industries, Inc.*

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Panel Instruments

Panel instruments, including a-c and d-c ammeters, milliammeters, microammeters and voltmeters, are now available in the new Model 1900 series. Featuring a common base and shell for various mechanism types in each of the most used instrument sizes, the new meters come in rectangular cases of clear plastic or Bakelite, with optional 1 or 2% accuracy in either case style. *Weston Instruments Division, Daystrom, Incorporated.*

Circle number (52) on reply card.

Pipe Dimension Chart

Pipe dimension chart shows outside diameter and wall thickness for all sizes of pipe from ½ through 42 in. It includes information from ASA Standard B36.10, showing IPS and schedule numbers and their relationship. Suitable for desk or wall mounting, the 17 by 11-in. chart is a convenient reference, eliminating need for referral to standards booklets. *Midwest Piping Division, Crane Co.*

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Pressure Switches

Leak-proof, adjustable pressure and differential pressure switches for use in fluid systems operating at up to 250 psi are covered in Bul-

letin E8. Included are Deltadyne switches adjustable within the differential pressure range of 0.125 to 16 psi. *Pall Corp.*

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Plastic Pressure Pipe

Duracor reinforced plastic pressure pipe resists corrosion and is capable of withstanding pressures up to 100 psi at temperatures as high as 250 F. Available in 10 and 20-ft lengths and in wall thickness ranges from ¼ to ⅝-in. Standard fittings are provided, as are joining kits that comprise all necessary materials for field joining. *Ceilcote Co.*

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Priority Relief Valve

Complete isolation of any portion of hydraulic or pneumatic systems below a preset point is possible with the new P-458 priority relief valve, which operates at pressures to 2000 psi. Actuation is accomplished by absolute system pressure rather than differential pressure between the inlet and outlet. Fail safe valve closure is effected by positive spring pressure whenever downstream pressure drops below design closing pressure. *Circle Seal Products Co.*

Circle number (56) on reply card.

Proportioning Pump

Proportioning pump designed for metering, sampling, treating and injecting applications in refineries and petrochemical plants is discussed in Bulletin A10. *Afton Engineering Co.*

Circle number (57) on reply card.

Rotocycle Meter Data

Rotocycle meters for all liquid metering applications are illustrated and described in detail in Catalog P-100. Specifications and dimensions of 14 basic Rotocycle meter types permit selection in any size range and capacity, from 14 to 1000 gal per min. *Rockwell Manufacturing Co.*

Circle number (58) on reply card.

Rubber Expansion Joint

AMR (anti-migration rubber) expansion joint provides same flexibility but 60% more capacity for withstanding high working pressures than standard joints. Unique inner construction enables the metal re-enforcing rings to remain stable under pressure. Joint can handle corrosive materials and withstand a wide range of temperatures. *United States Rubber Co.*

Circle number (59) on reply card.

Pump Sizing Bulletin

Pump bulletin (143) provides size selection chart, design cross-sections, mounting and space-occupancy dimensions for two new designs of double-volute, single-stage centrifugal pumps. Both Type DS and Type DL incorporate an axially split case that provides for unusually easy access. *Pacific Pumps, Inc.*

Circle number (60) on reply card.

SAMA Standards

Accuracy and sensitivity terminology as applied to industrial instruments (RC-3) is one of 14 SAMA standards for indicating and recording instruments and automatic controls listed in new bulletin, which gives particulars on how copies of individual standards may be obtained. *Recorder-Controller Section, Scientific Apparatus Makers Assn.*

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Sea Water De-Salting

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venture with the Israeli government. Unit embodies a vacuum freezing process. *Fairbanks Whitney Corp.*

Circle number (62) on reply card.

Semi-Steel Valves

Semi-steel valves and accessories are detailed in revised 44-page Bulletin V-203. Accessories discussed include wrenches, locking devices, extensions, lubricants and the new Rockwell Hypregun for lubricating valves. *Nordstrom Valve Division, Rockwell Manufacturing Co.*

Circle number (63) on reply card.

Screws Drive Like Nails

Helyx tempered drive screws, which drive like nails but turn and hold like screws, will not back out like ordinary smooth shank nails and cost less than screws. No drilling is required, even for hard wood. Special models for various applications, including driving into concrete. *Hillwood Manufacturing Co.*

Circle number (64) on reply card.

Shell and Tube Exchangers

Shell and tube-type heat exchangers recently added to the R. P. Adams line are described in Bulletin 715. The new line of heat exchangers initially features U-bend tube designs and straight tube designs with either fixed or removable tube bundles. *R. P. Adams Co., Inc.*

Circle number (65) on reply card.

Shutoff Valve Specs

Sentry shutoff valves are covered in Bulletin 500-2, which gives specifications, schematic drawings. *Coppus Engineering Corp.*

Circle number (66) on reply card.

Slide Rule for Valve Sizing

Slide rule solves for C_v and corrects for steam quality, gas specific gravity and temperature; also for liquids specific gravity and viscosity. Simplifies task of sizing control valves for known conditions of flow, pressure, etc. Standard A, B, C and D scales are also incorporated. *Fulton Sylphon Division, Robertshaw-Fulton Controls Co.*

Circle number (67) on reply card.

Space-Saving Rotameter

Metal-tube alarm rotameter, the Fig. 1900-F-CDA, saves space as result of the visual indicating element and alarm system being included in one housing. This cuts down on headroom requirements common to previous type designs where tube, visual indicating element and alarm system were mounted separately, one above the other. *Schutte and Koerting Co.*

Circle number (68) on reply card.

Standards Cataloged

Catalog of American standards, which now number 1973, contains a listing of special publications in the standardization field, pamphlets and standards recommendations of the International Organization for Standardization and the International Electrotechnical Commission. It also has an index to titles of American standards and international recommendations. *American Standards Assn.*

Circle number (69) on reply card.

Tank Heater Rating Data

Tank heaters—Type KV-244 vertical and KH-223 horizontal models — are illustrated and described in bulletin that gives complete rating data for all sizes of tanks and duties. *Griscom-Russell Co.*

Circle number (70) on reply card.

Specialized **EFCO** *Experience*

Solves Specific HEAT TRANSFER PROBLEMS...

Years of experience in engineering and fabricating of heat exchangers for the wide range of temperatures/pressures encountered in refining-petrochemical-natural gasoline plant processes enables EFCO to offer service-proved engineering design and guaranteed job rating. Gulf Oil Corporation is one of many process equipment users who are benefiting from EFCO's specialized experience and engineering efficiency.

This Gulf Oil Corporation installation of Efco units, in Gulf's Port Arthur Refinery, is typical of the many high-pressure, high-temperature exchangers designed and fabricated by EFCO.

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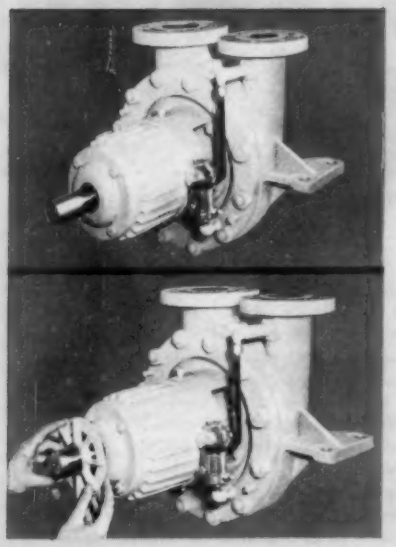

Models SMJ and SMJI Process Pumps

Now an exclusive *fan cooled* bearing housing available on Byron Jackson SMJ and SMJI Model Process Pumps can entirely eliminate a cooling water supply to the bearings! This feature was designed to eliminate engineering, installation, maintenance and operation costs of a cooling water supply, and can prevent costly freeze-ups in severe climates.

Simple, efficient and trouble-free, it works like an air-cooled electric motor. A fan mounted on the shaft behind the bearing draws cool air over the thrust bearing and out over the cooling fins of the housing. For lower temperature service the same pump can be used as a simple air cooled bearing, without the fan and fan cover, using the cooling fins alone to dissipate heat.

Only two different bearing housings fit all models of vertical SMI and SMJI's up to 300 horsepower, and either may be adapted to fan or water cooling when purchased or after installation.

As the first major improvement in Process pump design in years, this fan cooled bearing was developed to meet a long-existing need of the industry. Investigate the economy and efficiency of this really new line of pumps. Call or write for descriptive literature.

A complete new line of

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For Speediest Repair of Corrosion Leaks in Pipe

JUNIOR

EMERGENCY PIPE CLAMP

Repair pipe leaks QUICKLY!

Speediest application — slotted lug permits the single plated bolt to slide instantly into place.

A companion to the old reliable Emergency Pipe Clamp that has served industry for a half century, the JUNIOR, a single bolt clamp, is 2⅞" wide. Undersells most band-type clamps.

Made of malleable iron, ruggedly proportioned, with full-length hinge along one side. Formed to exact pipe size—no bending. The recessed pressure-equalizing gasket, entire width of clamp, is cemented in. A lasting installation. 2" pipe size—$1.80; 2½"—$2.20; 3"—$2.30. Write for new circular on the Junior.

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EMERGENCY PIPE CLAMPS for safe, sure lasting repair of splits and rust holes in pipe. No pressure too high. Anyone can apply in a few moments. Made in all sizes, ½" to 12", for steel and C. I. pipe. Stocked by practically all oil supply stores.

Send for catalog!

M. B. SKINNER CO.

SOUTH BEND 21, INDIANA

Steel Pipe Fittings

Fittings catalog describes wide variety of stainless steel pipe fittings for HPI service at from 150 to 6000 psi. *Valve & Fitting Division, Cooper Alloy Corporation.*

Circle number (71) on reply card.

Tank Suction Heaters

Paracoil tank suction heaters, for either intermittent or continuous removal of highly viscous fluids from tank storage, are explained in 16-page Bulletin 60-J1. Capacity tables for various heating ranges are included, together with dimensions and weights. *Davis Engineering Division, Tube Reducing Corp.*

Circle number (72) on reply card.

Thermocouple Material

Tempak metal-sheathed ceramic-insulated wire and thermocouple material is treated in new 10-page catalog. *Temptron, Inc.*

Circle number (73) on reply card.

TMB Product Information

Trimethoxyboroxine (TMB) product information is contained in 12-page Bulletin CT-520, which describes properties, uses, handling. Principal applications of TMB are as a metals fire extinguishant, as a primary curing agent for epoxy resins, and as an agent for nitrogen removal from refinery feedstocks. *Callery Chemical Co.*

Circle number (74) on reply card.

Transfer Pump Spec Sheet

Liquid transfer pumps, the MX and MXS motor-mounted series designed for handling clean liquids and solvents (up to 5000 SUS), are subject of a new specification sheet. These pumps offer new economy and ease of installation on jobs requiring delivery rates from 10 to 30 gpm at pressures up to 125 psi. *Blackmer Pump Co.*

Circle number (75) on reply card.

Tubing, Pipe Stock List

Tubing and pipe stock list details what's available in alloy and stainless steel. *Tubular Products Division, Babcock & Wilcox Co.*

Circle number (76) on reply card.

Valve Catalog

Diaphragm motor valves for HPI applications are detailed in new catalog. *A. W. Cash Co.*

Circle number (77) on reply card.

Valve Sizing Data

Accurate valve sizing for flashing liquids is explained in Technical Bulletin 108, written by A. J. Hanssen, Conoflow Corp.'s chief engineer. It gives formula based on downstream density of the liquid vapor mixture and curves for some of the most commonly used fluids. Thus the instrument engineer using this approach can accurately size a valve for flashing fluid conditions with only a few simple calculations. *Conoflow Corp.*

Circle number (78) on reply card.

Valves, Accessories

Valves, actuators and accessories . . . are detailed in 36-page catalog, Bulletin 061A. Sizing data and pressure-temperature graphs are included. *Security Valve Co.*

Circle number (79) on reply card.

Wraparound Saddles

ShurSeal wraparound service saddles are subject of new bulletin that gives sizes, specifications. Saddles are available in single and double strap models; in malleable iron, ductile iron or bronze, and in sizes from 1¼ to 12 in. They are said to give positive seal on the roughest pipe, require less bolt tightening and provide increased sealing as pressure increases. *R. H. Baker & Co. Inc.*

Circle number (80)on reply card.

Zinc Fingers

Zinc anode plug assemblies specifically designed for water protection in all types of heat exchangers are described in specification sheet. These zinc "fingers" can be used in heat exchanger systems with pressures up to 200 psig. *Butler Engineering Associates, Inc.*

Circle number (121) on reply card.

ARKANSAS LOCATION

3 — Worthington 3500 CFM air compressors, 24 x 15, Model #LTC-4, with 500 HP natural-gas engine drive.

1 — Chicago-Pneumatic 3060 CFM air comp., 60 PSI, #19-32-30-18x24, steam driven.

20 — 27,500 gal. horiz. steel tanks, ASME 75 PSI WP.

PERRY EQUIPMENT CORP.

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MIAMI STANDARDIZES ON GAR WOOD-BUCKEYE

GAR WOOD-BUCKEYE 315, *owned by the city of Miami, cuts through coral rock for a six-inch water main. Note clean sides of ditch, precise placement of spoil pile.*

City Finds Buckeyes Best for Solid Coral

Whether you call it coral rock, keystone coral or Florida lime—it's hard—and it comprises 60% of the Miami terrain. Ditching through solid coral can wear out a set of rooter bits in a single day. This is *really* tough ditching, and to do it the city of Miami has gone exclusively Gar Wood-Buckeye.

Miami owns 10 Buckeyes. According to John Layton, Maintenance Foreman for the Miami Water Board, "Buckeyes are by far the best ditchers for cutting through solid coral. And they are the best *all-around* ditching machines we have ever used."

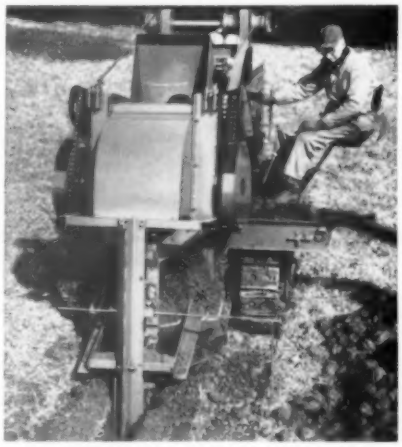
Another reason Buckeyes have proven superior in Miami is low maintenance. "Coral rock is plenty punishing," says Layton, "but it hasn't stopped our Buckeyes. They continually ditch at top-notch efficiency. And they require less maintenance than any other ditchers we've ever tried."

Buckeye ditchers are the most modern on the market. Every major engineering development in ditching for the past 68 years has been found first on Buckeye ditchers. Today Gar Wood continues to set standards in the field—giving contractors and municipalities across the country high production, low maintenance, and long, trouble-free operation.

MIAMI DITCHES SERVICE LINES WITH GAR WOOD-BUCKEYE 403

Ditching for service lines requires a highly maneuverable machine. Miami has found that the best machine for the job is the Buckeye 403.

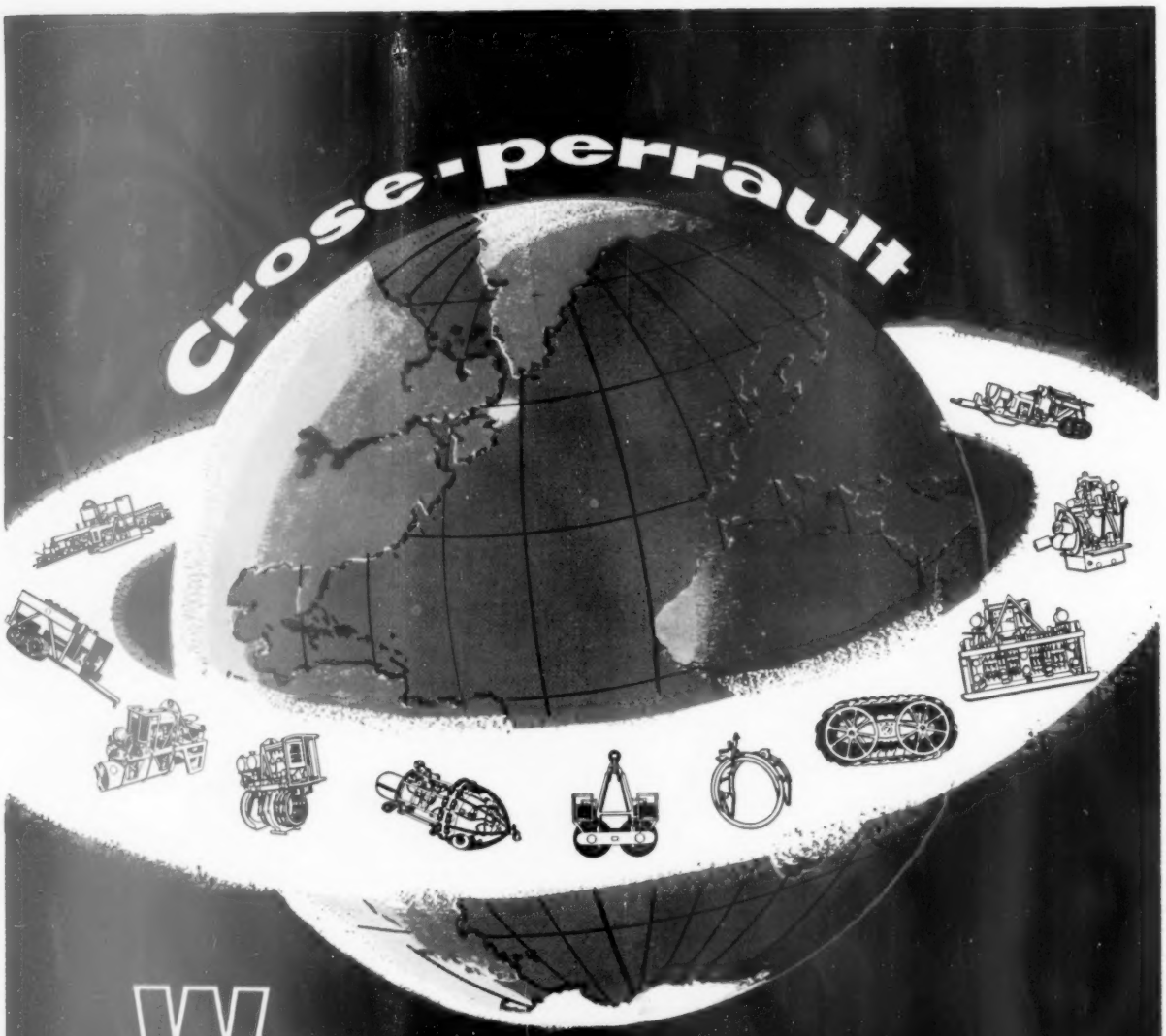
This crawler-mounted, ladder-type ditcher operates well over all types of ground, digging a clean, straight-sided trench with square corners that require no hand forming. The 403's low ground bearing pressure—7.5 psi—won't damage lawns or walkways. A hinged crumber shoe folds back to allow digging up to foundation walls and for undercutting obstructions. The machine is transported easily and quickly on a tilt-bed trailer.



The Buckeye 403 is another example of Gar Wood's outstanding ditcher engineering—engineering to provide contractors and municipalities with specialized machines that dig far more ditch at far less cost.

GAR WOOD INDUSTRIES, INC.

Wayne, Michigan • Findlay, Ohio



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Shaping the Future

INDUSTRY EXPANSION

The gas industry will borrow $10 to $15 billion during the next decade, Lester T. Potter, president of the American Gas Association and Lone Star Gas Company, told the New York Society of Security Analysts, the money to go for expansion. At the beginning of 1961, plant value was $21.8 billion. This includes pipelines.

DJ INVESTIGATION

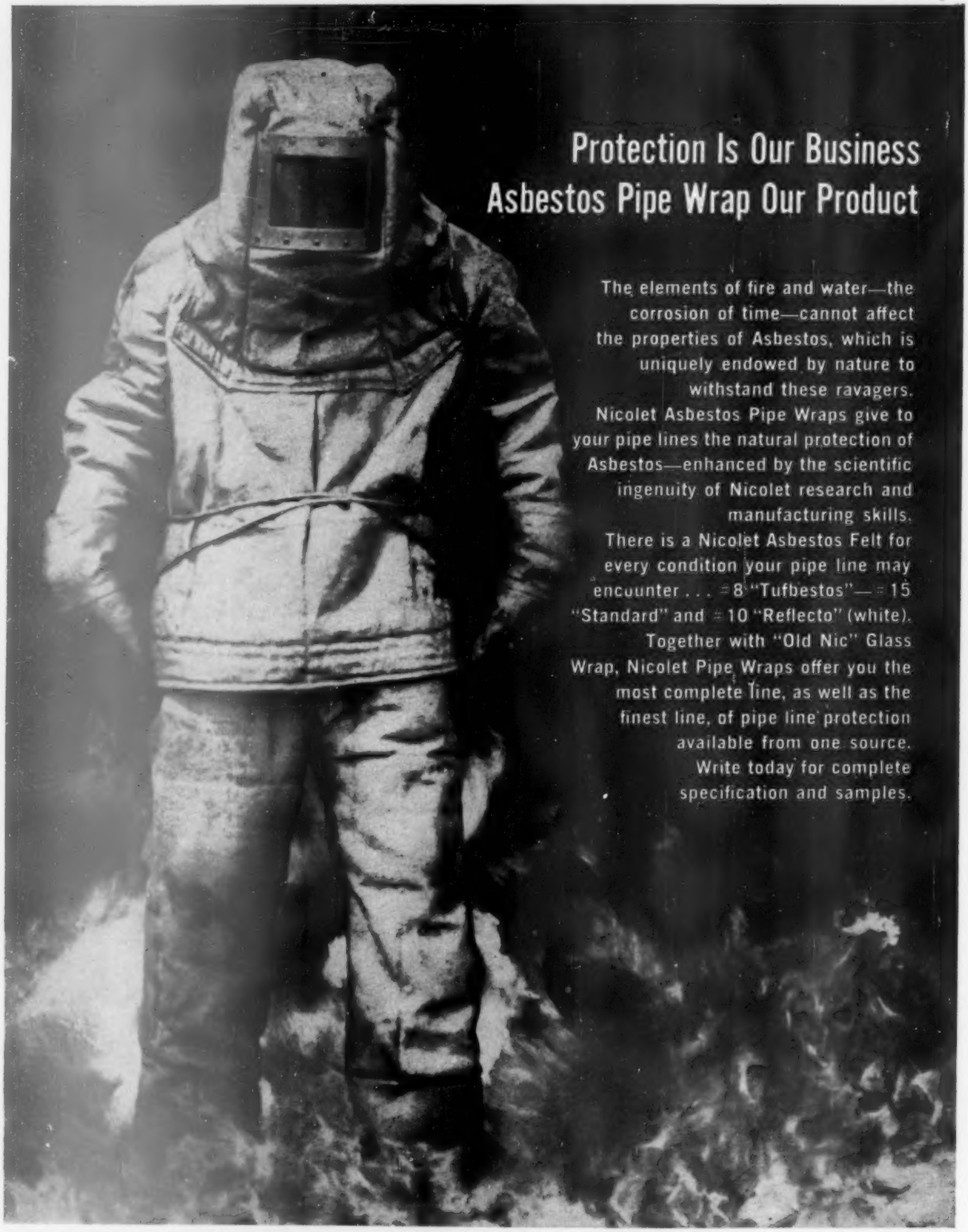
Is the Department of Justice about to launch an investigation into the ownership of pipelines by shipper refineries? Lee Loevinger, antitrust chief, indicated as much at hearings before the House Antitrust Committee on the 1941 Elkins Act consent decree. He said "refinery ownership of pipelines presented serious antitrust problems." He further said the Elkins Act is "ineffective" because of court decisions and changed conditions.

AUTOMATIC WELDING

Faster construction time and reduced costs have been the basis for continued efforts over the last several years to develop a means of automatic welding line pipe in a fixed position. How to keep the weld metal from running out of the groove has been the main obstacle. Two processes have been announced within recent weeks that have proved successful in field usage. One is the Price-Crose-Perrault-Hobart system, the other was developed by Esso Research and Engineering. Details of how the latter method works are given in a special article in this issue.

PIPE PRICES DROP

A cut in line pipe quotations by the steel industry gives rise to speculation on what the future trend may be. With an increase in steelworkers' pay going into effect October 1, an across-the-board rise in steel prices was looked for this fall. Now there is a big question mark. Steel officials say the price cuts were made because of stiff competition from foreign mills and small domestic producers. Some of the latter buy semi-finished steel, often from abroad, and make a finished product that sells at reduced price levels.



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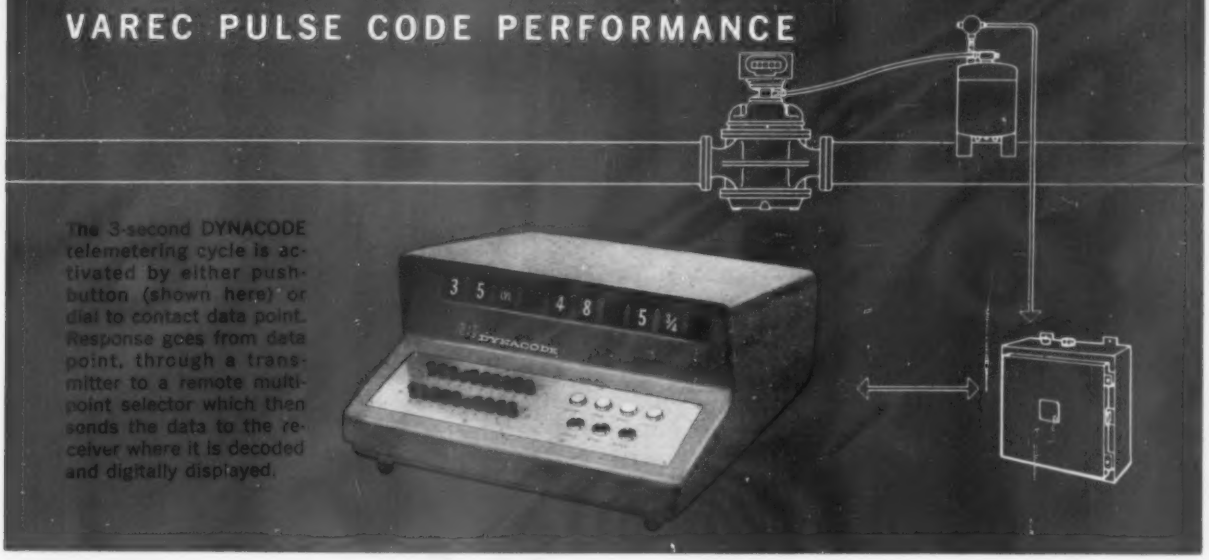
DYNEL DYNACODE TELEMETERING SYSTEM

A NEW HIGH-SPEED REMOTE MONITORING SYSTEM BASED ON 6 YEARS OF FIELD PROVEN VAREC PULSE CODE PERFORMANCE



The 3-second DYNACODE telemetering cycle is activated by either push-button (shown here) or dial to contact data point. Response goes from data point, through a transmitter to a remote multi-point selector which then sends the data to the receiver where it is decoded and digitally displayed.

Dynel engineers—utilizing the performance proved concepts of Varec's famous Pulse Code system—have developed the significantly advanced DYNACODE telemetering system for remote readings of liquid level, temperature and P.D.M.

This single-channel, "error-proof" system combines the proven reliability of the basic Varec system with a digital readout time of 3 seconds per point... readout accuracy of 1/16 inch... readout capacity of an unlimited number of points... and readout versatility that permits the system to be tied into a general purpose computer for inventory, billing, and similar functions.

Solid state components are used at key points in the receiver design for longer, maintenance-free life. And DYNACODE, like Varec's Pulse Code, has an instantaneous alarm system without scanning delays.

The high-speed DYNACODE System offers these advantages:

Reliability: Design based on 6 years of performance in scores of pipeline and refinery applications.

Data Display: Illuminated, in-line digital display includes point and function identification, digital data to 6 significant figures and liquid level to 1/16" increments.

Fast Response: data from any given point is gathered and digitally displayed in just 3 seconds.

Flexibility: Designed on building block principle that permits a great variety of system arrangements... DYNACODE is compatible with all standard systems of measurement.

Readout Variety: digital output provides a variety of readouts, including visual display, paper tape, typewriter, etc. Output is compatible for use with general purpose computers.

For complete information, see DYNACODE at the ISA Show, Los Angeles Sports Arena – Booth #170. Or write for Bulletin 301, Dept. PTE-1600-1

DYNEL, Inc., *a subsidiary of Varec, Inc.*

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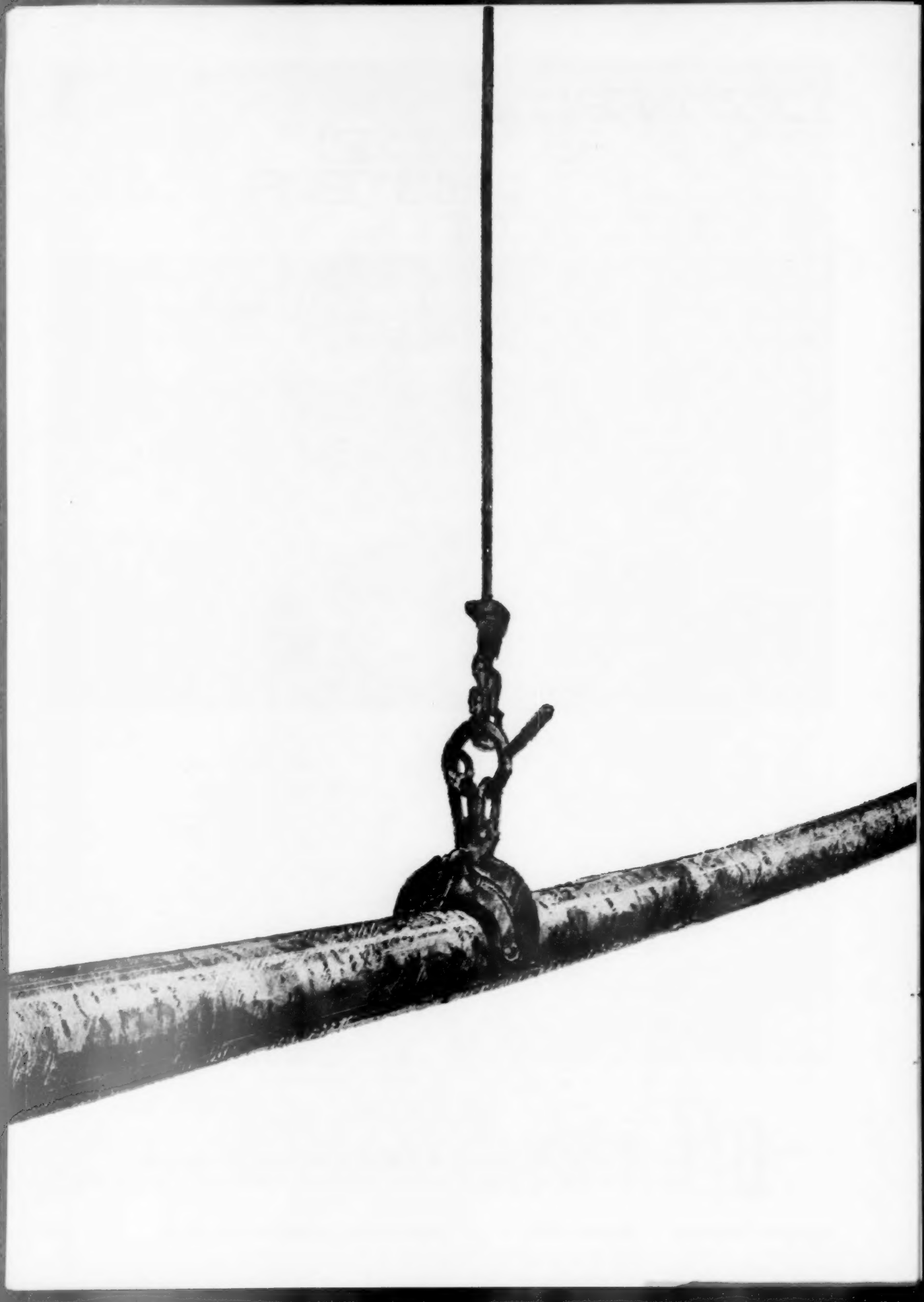


FOR THE UPS AND DOWNS OF DIFFICULT TERRAIN

J&L Electricweld Line Pipe. Mountainous country gives you a good indication of the quality of line pipe. It places a premium on the ability of pipe to bend to contour. And keeps you keenly aware of such factors as weldability and roundness.

Real line pipe quality begins with the steel itself. That's why J&L offers you such certainty. As a major steel producer, J&L controls line pipe quality from iron ore to finished product. Every length of J&L Line Pipe is produced on one of the most modern mills in the world. Welds are ultra-sonically tested and are sound from end to end. And you get pipe that is uniformly round and easy to weld on the job. J&L Line Pipe is available from 6⅝ inches through 12¾ inches.

Jones & Laughlin Steel Corporation

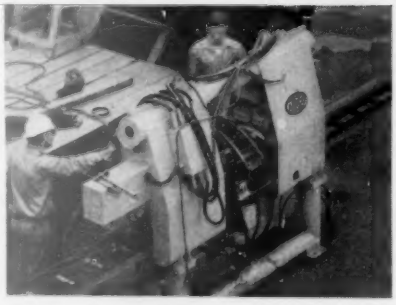
3 Gateway Center, Pittsburgh 30, Pennsylvania

J&L STEEL

Announcing the

NEW AIRCOMATIC® PIPE LINE WELDER

Now . . . production speed brought to pipe line welding . . . in the field in any weather . . . without pipe rotation.



For welding speeds up to 20 times faster than manual rates — the Aircomatic Pipe Line Welder requires only one welding technician, an assistant and a tractor operator, plus the usual line-up crew.

Operation. With square butt-ended pipe in position, the Aircomatic Welder is lowered. Pipe ends are aligned and clamped. Amperage, voltage, welding speed and alignment control are preset. A power grinder slices a narrow channel through one half of the joint from 12 to 6 o'clock. The Aircomatic Welder follows the grinder to perform the weld, in one pass, under a CO_2 shield. No hand steering is needed. Following the first weld, a slot then is cut through the opposite half of the joint, and the second weld completed.

Results. The Aircomatic Pipe Welder can finish a circumferential weld in one minute . . . compared to 20 minutes for a manual weld. Welds are slag-free. Weld strength exceeds that of the pipe.

Soon available on a lease basis are Aircomatic Welders to handle 4, 6, 8, 10, 12, and 14 inch pipe. Larger models will be ready shortly. For further information write Airco today.

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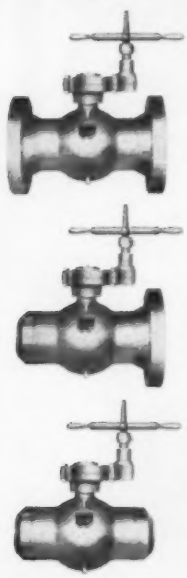

"The Cameron Ball Valve was approved by our engineers for its compact design, rotating seats to distribute wear, lack of bonnets or glands and its sealed-for-life construction. The operating men like its ease of installation, low-friction operation, lack of lubrication and lack of maintenance. Management appreciates not having to stock repair parts, the lack of down time, and the prompt delivery in a wide range of sizes and pressures . . . and the outstanding performance on our test installations really sold us." Have you carefully considered the many features Cameron Ball Valves offer?

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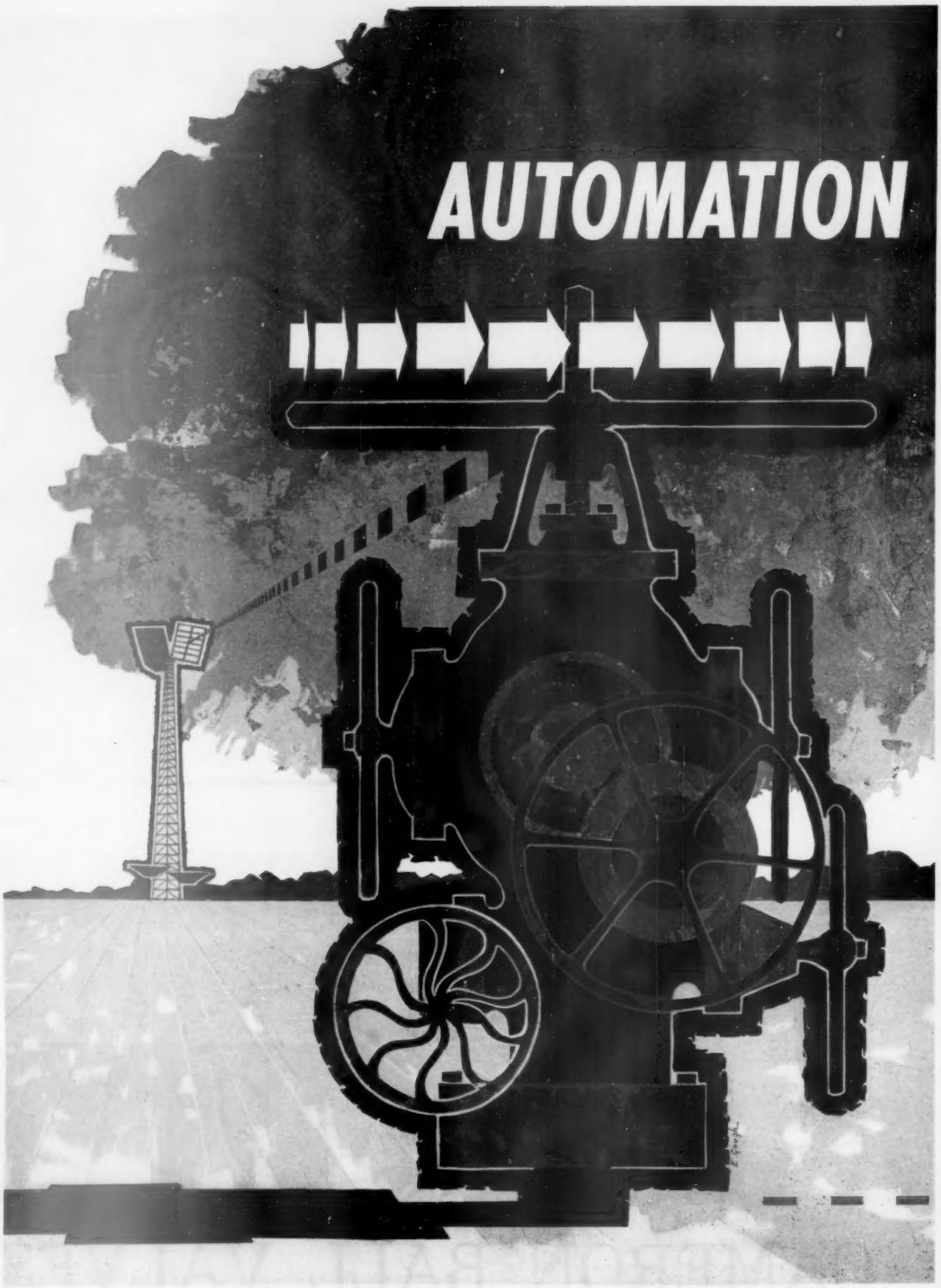
AUTOMATION

THROUGH COMMUNICATIONS

works wonders in integrating pipeline operations

Nothing on the horizon holds greater promise of reducing pipeline operating costs than *automation through communications.*

Lenkurt electronic systems place virtually all communications in one package for fully integrated, system-wide communication at high speed – telephone, teletype, digital data, telemetering *and* fully automatic remote control of pumping and distributing stations.

As a leading specialist in microwave and carrier, Lenkurt Electric is ready now to put these modern communications systems to work for *you.* And Lenkurt Electric has the talents and the resources for handling a complete system-wide installation from start to finish.

It will pay you to explore Lenkurt's complete line of communications systems in your modernization program. A letter or phone call to your regional office will bring quick results.

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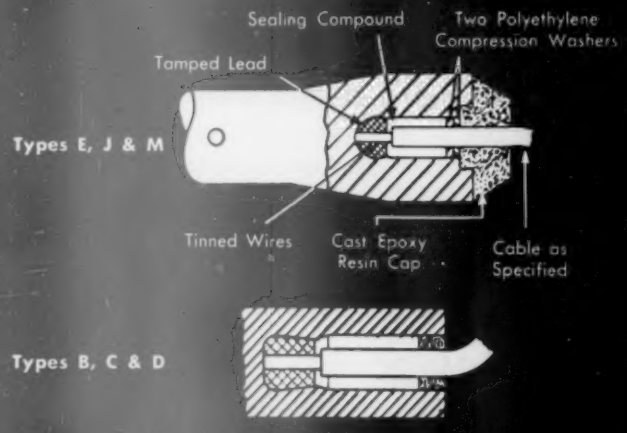
Standardize on DURIRON! In the normal ground bed installations with perfectly (or imperfectly) tamped backfill, DURIRON gives positive protection. But in the tough applications; marshlands, river crossings, or wherever backfilling is impractical, DURIRON outperforms all others. DURIRON can be used without backfill! Buy DURIRON anodes for complete protection with long service life in the toughest services. (And in the easy ones, too.)



STOCK DURCO ANODE SIZES

Type Anode	Size	Area Sq. Ft	Weight (Lbs.)	General Application
B	1" x 60"	1.4	14	Fresh Water
C*	1½" x 60"	2.0	25	Ground Bed
D	2" x 60"	2.6	46	Ground Bed
E	3" x 60"	4.0	115	Salt Water
G	2" x 9"	0.4	5	Ducts
J	3" x 36"	2.5	80	Salt Water
M	2" x 60"	2.8	57	Salt Water

*Applicable also in fresh water service. Should not be used in ground beds without backfill.

THE DURIRON COMPANY, INC. / DAYTON 1, OHIO

DURCO

40 GROVE G-5 GATE VALVES USED IN SHELL'S MANIFOLD MODERNIZATION

One of four Shell oil-gas gathering system manifolds at Gibson, La. Forty 3" Grove G-5 ASA series 150 Seal-"O"-Ring Gate Valves.

In modernizing its Gibson, La., oil-gas gathering system manifolds, Shell Oil purchased Grove series G-5 gate valves. These valves feature Grove Seal-"O"-Ring® design—the "double-barrier" sealing system. First, there's positive metal-to-metal seal of inner seat rings against a parallel sided gate. Second, the sealing and squeegee action of protected o-rings that keep the gate clean and smooth for fast, easy open and close. Other G-5 features: extremely compact, round opening, kanigan coating to resist corrosion. And the big plus: Grove G-5 gate valves eliminate all maintenance costs relative to lubrication!

Call or write for a complete Grove G-5 valve presentation

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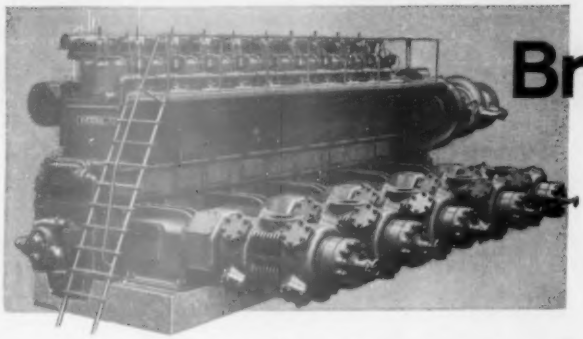
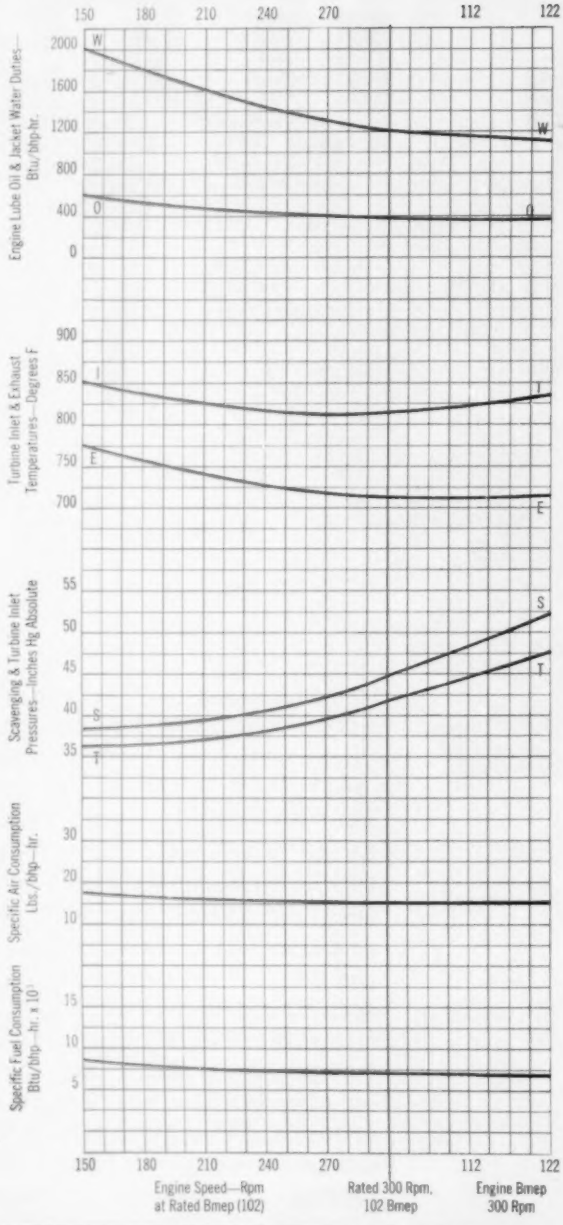


Breakthrough in two variable speed,

Automatic ignition timing plus automatic turbocharger control provide unrivaled speed, load and response characteristics.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Specific Air Consumption Lbs./bhp—hr.
30 20 10
Specific Fuel Consumption Btu/bhp—hr. x 10
15 10 5
Engine Speed—Rpm at Rated Bmep (102)
Rated 300 Rpm, 102 Bmep
Engine Bmep 300 Rpm

Performance curve of Clark Model TLA turbocharged, 2-cycle, gas-engine-driven compressor. Unit features 17"x19" bore and stroke. Rated speed is 300 rpm. Rated bmep is 102 psi. Note the remarkable parallel between the fuel consumption and specific air consumption curves.

Q. What makes two cycle engines so well suited for variable-speed, variable-load applications?

A. It has long been traditional to consider two cycle engines as good prime movers for applications where power and speed are maintained close to 100% of rated load and speed. This may have been true a number of years ago when two cycle engines were single and twin horizontal designs. But the situation began to change with the introduction of vertical, multicylinder machines with direct fuel injection. Subsequent addition of constant pressure turbocharging and automatic ignition timing control have made two cycle performance equal or superior to four cycle engines in acceleration and in response to load or speed changes. Regardless of how fast the load or speed changes, the two cycle engine is able to adjust more rapidly because it fires twice as frequently. As a result the actual amount of load change between successive firings is cut in half, all other conditions being equal.

Q. Why has turbocharging caused such a vast improvement in two cycle engines?

A. The Clark system of constant pressure turbocharging permits variation of scavenging air flow with load to maintain relatively uniform air/fuel ratios over the complete operating range. This variable air supply plus maintenance of optimum ignition timing enables Clark engines to achieve excellent performance from substantial temporary overloads at rated speed down to the usually recommended 50% speed at constant torque.

Q. Why is constant pressure turbocharging so effective?

A. In general, all turbocharged engines are arranged to achieve best efficiency and fuel consumption at a particular design point—usually rated load. The Clark system of constant pressure turbocharging, however, is inherently capable of maintaining optimum efficiency not only at design point, but over an extremely broad operating range as well. The reason: *Clark turbocharging provides a flexible supply of combustion air that varies in direct proportion to load.* It does not depend on pulses of exhaust gas or on engine driven blowers, hence is free to provide the exact amount of air demanded by the engine. At light loads, there is neither a fall-off in performance nor any "lean out" problem arising from too much air. With increased loads, the turbocharger is able to pump increasingly more dense scavenging air into the power cylinders. There is no element in the

cycle compressor performance for variable load applications

system to impede or interfere with the performance of the turbocharger as it responds to the higher power requirements. Thus the fuel/air ratio remains constant through the entire operating range for best engine performance.

Q. Are there other important advantages of the Clark Constant Pressure Turbocharging system?

A. Yes. In addition to efficient combustion, the large amounts of available scavenging air have a cooling effect on the cylinder walls, cylinder heads and piston heads. Possibility of detonation is minimized, better lubrication is assured, and the temperatures of the exhaust gases are controlled as they enter the turbocharger. The cooling effect of the excess scavenging air is especially advantageous at high ambient temperatures. It lowers overall cooling duty and enables the Clark intercoolers to provide adequate scavenging air cooling. There is no need to resort to evaporative cooling of air or other special means of preventing detonation and cylinder wear.

Q. How does Clark achieve such good low speed lugging characteristics?

A. With Clark turbocharged, two cycle engines, compressor capacity can be most easily and efficiently varied by adjusting speed while maintaining at or near rated load torque. *The engine-driven compressor is then operating at rated load all the time, at which condition it functions most efficiently.* The exceptional low speed lugging characteristics are due primarily to frequent power impulses that reduce cyclic speed variation. At low speeds, cyclic speed variation is always accentuated because flywheel inertia is reduced in proportion to the square of speed reduction, and power impulses become less frequent with respect to time. Thus the two cycle engine has a great advantage because each cylinder fires every revolution.

Q. How do Clark two-cycle engines perform under overload conditions?

A. A glance at the chart showing actual test data taken from a Clark turbocharged Model TLA gas-engine-driven compressor demonstrates graphically that the fuel consumption curve is remarkably flat over a wide range. When operating as high as 20% overload under emergency conditions, Clark engines actually burn *less* fuel per bhp than at rated load. Even more important is the manner in which the specific air and specific fuel consumption curves parallel each other perfectly over the entire range. This illustrates the inherent advantage of Clark "true" turbocharging system. Once the engine is started and the turbine is self-sustaining, the turbocharger adjusts itself freely and almost instantaneously to the demands of the engine.

Q. How does ignition timing control improve operating performance?

A. There are two conditions in which ignition timing control is used with the Clark system: At startup and at reduced speeds. During the starting cycle, the timing control automatically adjusts the ignition to increase the flow of heat to the turbocharger. This shortens startup time and substantially reduces consumption of starting air.

At reduced speeds (i.e. from 50% to 80% rated speed), the ignition is automatically regulated to maintain optimum ignition timing consistent with the rate of pressure rise in the cylinder with respect to time. Thus the peak pressure is reached at or near top dead center and expansion of the burned gases takes place most effectively with less tendency to detonation.

Q. What is the net effect of combining turbocharging with two-cycle engines?

A. The user enjoys all the advantages of a two-cycle engine—simplicity, fewer moving parts, greater dependability—plus the advantage of turbocharging—more power in less space, better fuel economy, greater operating flexibility. Clark two-cycle gas-engine-driven compressors are very conservatively rated. Lower bmep eliminates the ignition difficulties and fouling tendencies common in higher rated machines. There are no large exhaust or intake valves to warp, pit or burn. Two-cycle design keeps continuous downward pressure on the power pistons, thereby eliminating oil "pumping." There is no piston ring blowby, the cause of sludging and crankcase oil dilution. The two-cycle engine is less sensitive to detonation under high ambient temperatures. Thus Clark design reduces costly maintenance and assures more profitable "uptime."

Q. In what type of application is Clark capacity variation with speed useful?

A. Pipeline gas transmission where there are few units in a station. Process applications employing gas engine drivers. Gas distribution boosters where the compressors are located near sales outlets. Manufactured gas compressors. Field gathering compressors where few units can be economically employed and wide variation in gas supply is expected.

For more details on how Clark variable-speed, variable-load performance can help you, contact your nearest Clark office or write to:

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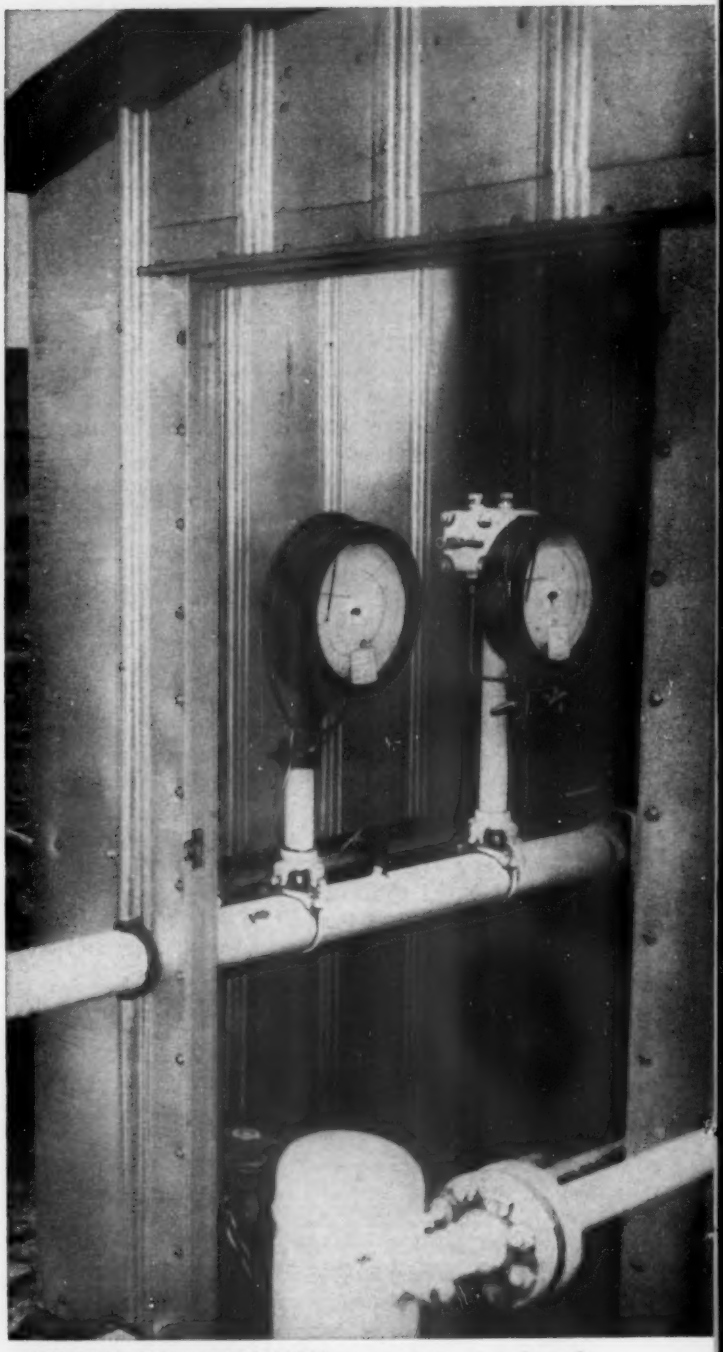

FOXBORO HIGH-PRECISION gas metering team in action at Transwestern Pipeline Company station, Parsell Field, Texas. Foxboro Anti-Ambient Temperature Recorder (left) and Foxboro T/37 Diaphragm Meter (right) measure purchased gas with "cash register" accuracy.

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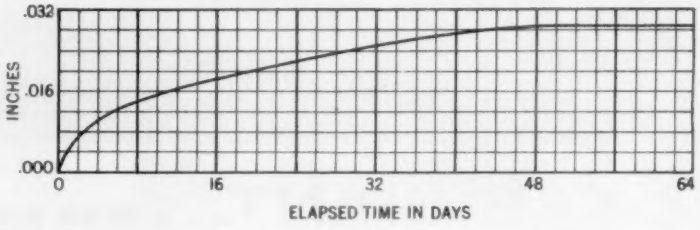
They're not alike, not in physical properties! When plastic insulators first became available for pipeline use, WmSON felt they were inferior to the steel and block types then available. We delayed our entry into the field until we could provide a plastic material to withstand field abuse and wear. We found that material in a high density polyethylene which could be injection molded to provide low cost insulators of the highest quality.

Our decision has proved sound. Breakage and excessive wear of glass fibre reinforced plastics, particularly in large sizes, has created a lack of confidence in plastics in general, but the M-2 Plastic THINsulator® has proved its stamina. Its high resistance to cold flow has been proved. Deflection test results: 1000 p.s.i. on each THINsulator runner for 64 days — total cumulative deflection only 0.029". Max. temp. during test, 105° F., min. temp., 75° F.



Its low coefficient of friction causes it to slide easily inside casing. The M-2 is completely resistant to impact fracture (4.0 ft. lbs./in. notched) and has successfully worked on 36" pipe, ½" wall, pulled in excess of 500 feet. We are convinced that it will perform as well or better than any other insulator on the market, including all known steel types. Other physical properties: *Dielectric strength* — (short time, ⅛" thickness) 500 volts per .001 inches (D149-55T); *Tensile strength* — 4400 p.s.i. at 20 in./min.; *Elongation* — 25% 20 in./min.; *Abrasion resistance* — Taber index 5.7.

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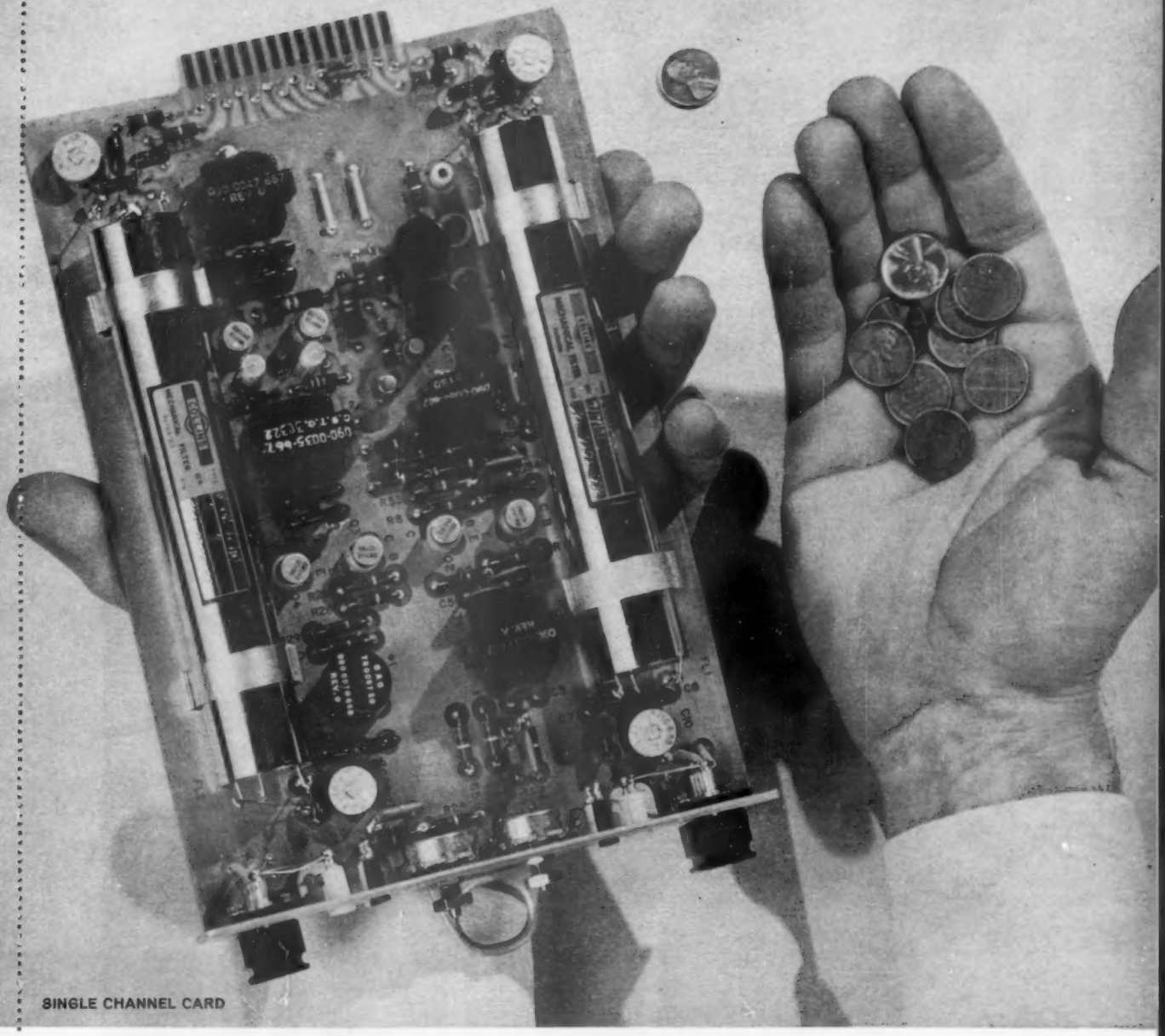

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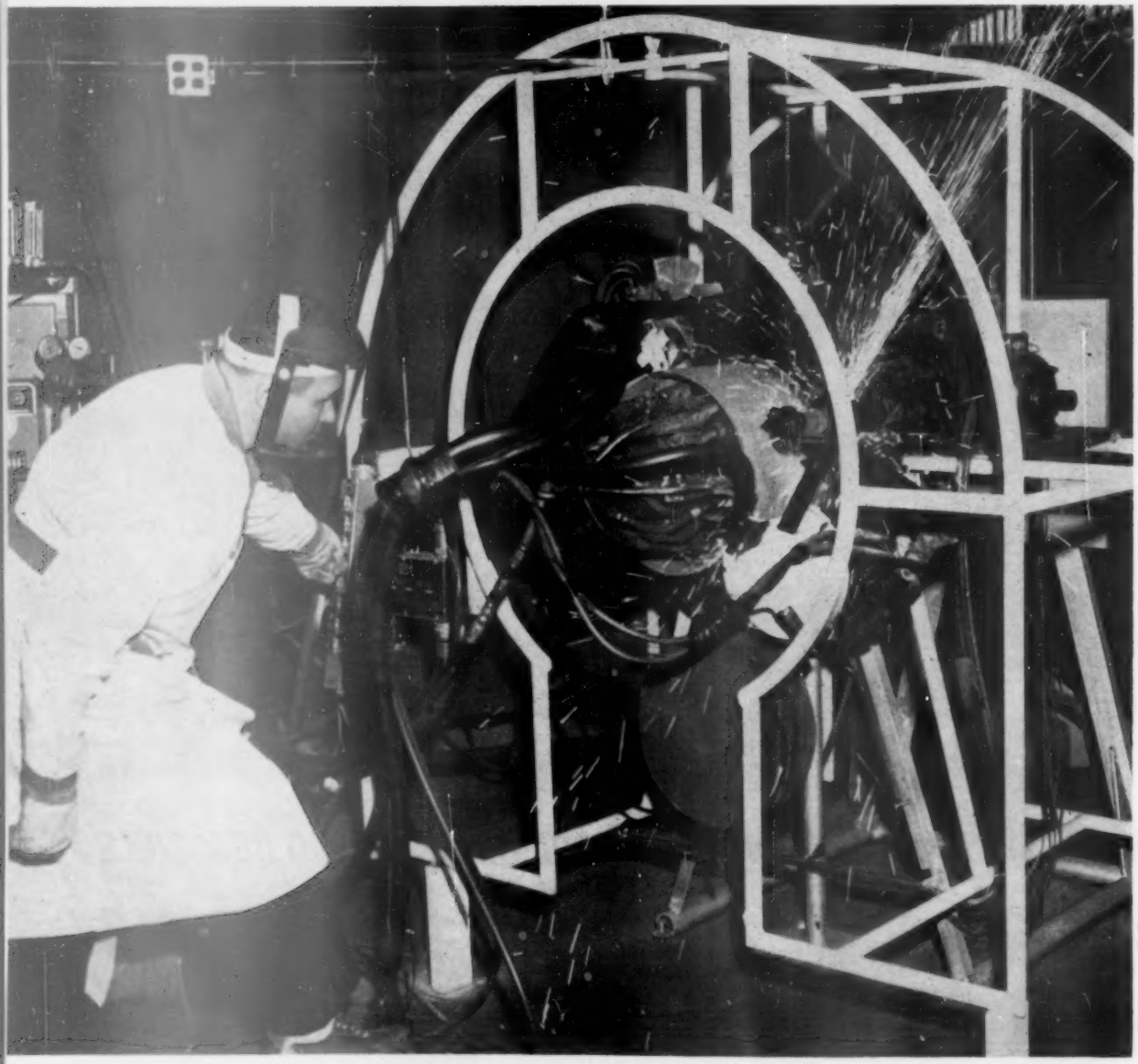


Fig. 1. Laboratory welding apparatus showing joint-preparation operation used with the automatic welding process.

Arc-Welding

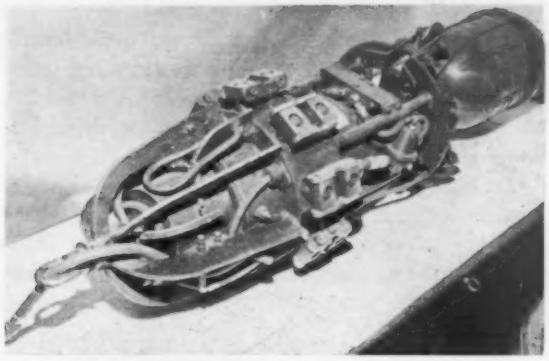


Fig. 2. Automatic pneumatic clamp fitted with pivoting knurled clamping shoes for use with process.

Excellent weld quality, high welding speeds, low manpower requirements, elimination of weld backing rings, and elimination of conditions that cause underbead cracking characterize a new automatic process for arc-welding girth joints in steel pipelines in a fixed horizontal position.

Overcoming the chief problem of keeping molten steel from flowing out of the weld joint in the vertical overhead positions, the automatic process permits: present pipeline construction rates to be matched or exceeded because welding speeds are as high as 55 ipm; single-pass welds in pipe with wall thicknesses of 5/16-in. or less; and adaptability to all pipe diameters.

The automatic process, developed at Battelle Memorial Institute under the sponsorship of Esso Research and Engineering Company, in general is a method for adapting CO_2-shielded consumable-electrode arc welding to pipe girth-welding operations.

Process Description

Three major operations are performed in making girth welds with the automatic pipe-welding process*:

1. The pipes are aligned for welding.
2. The joint is prepared for welding.
3. The weld is made.

Special equipment is used to prepare the joint and make the welds. The laboratory apparatus used for this purpose is shown in Fig. 1.

Conventional internally expanding alignment clamps are used to hold the pipes in position for welding. Such a clamp is shown in Fig. 2. The clamp is fitted with clamping shoes that bridge the joint to hold the pipes rigidly aligned. The clamping shoes are pivoted so that the clamp can be expanded into one pipe while the other pipe is lined up. When the second pipe is in position, the clamp is then expanded into the second pipe. The clamping shoes have knurled surfaces to facilitate rigid clamping.

Except for end preparation and joint spacing, the pipes are aligned by conventional procedures. The ends of pipe with wall thicknesses of 5/16-in. or less are prepared with square ends for the automatic process rather than the beveled ends used for manual welding. Also, the pipe ends are spaced so that they are almost touching for automatic welding rather than having the usual root spacing that is necessary for manual welding.

After the pipes are aligned, the pipe-welding machine is lined up with the joint and the automatic process is started. The sequence of the automatic process for making welds in pipe 16 in. or less in diameter is shown schematically in Fig. 3. First, the joint on one side of the pipe is prepared for welding from top to bottom. The joint is prepared by cutting a narrow space between the pipe ends with an abrasive cutoff wheel. The cutoff wheel is mounted on the pipe-welding machine. After one-half of the joint is prepared, it is welded in the downhill direction from the top to bottom of the pipe. A conventional gas metal arc welding head is mounted on the machine to make the weld. Next, the other side of the joint is prepared. Then, the second side is welded, again the downhill direction. When the second side is completed, the line-up clamp is removed and line-up of the next joint started. Both the joint preparation and welding operations are carried out at speeds of up to 55 linear ipm. Thus, a complete weld can be made in 16-in. diam, 5/16-in. wall pipe is slightly more than 2 min without an overlap of operation. A typical girth weld is shown in Fig. 4.

Another sequence is required for large-diameter pipes — for example, 30-in. diam. In order

*Apparatus and process patents have been widely applied for. Licenses have been arranged whereby Air Reduction Sales Co. can manufacture the apparatus and Crutcher-Rolfs-Cummings, Inc., and H. C. Bauer Associates can handle its distribution to pipeline interests.

to finish the welds in this size pipe in 2 min, it is necessary to prepare the joint and weld simultaneously with one or multiple cutting and welding units. Welding times as low as 1 to 1½ minutes can be anticipated with some automatic sequences.

Although the mechanics of the process appear simple, several novel features are incorporated into the process to make it work. One of these features is the geometry of the weld. Other features are the methods used to control welding conditions.

Weld Geometry

Weld geometry is one of the most important features of the process, because it represents an optimum relationship between the amount of molten weld metal deposited in the joint and the arc forces that control the flow of this metal. Weld geometry, in turn, depends on the dimensions of the prepared joint and the welding conditions that are used. All of these are carefully controlled in the automatic process.

Cross-sections of typical girth welds that are obtained with the process are shown in Fig. 5 and 6. Fig. 5 shows a cross-section of a single-pass weld made in pipe with a nominal wall thickness of 0.280 in. This weld is made with a square butt joint with a root spacing of about 1/16 in. Single-pass welds are made in pipes with wall thicknesses of 5/16 in. or less. Fig. 6 shows the cross-sections of two-pass welds in ⅜-in. wall pipe. The joint dimensions of the two-pass weld are designed so that the root pass simulates the square-butt joint used with the single-pass weld.

The joint geometry features of the automatic process are characterized by the single-pass weld shown in Fig. 5 and the root pass of the weld shown in Fig. 6. These welds are very narrow and have depth-to-width ratios of about 2. This narrow weld results from the square-butt type of joint, high welding speeds and other welding conditions that are used. There is only a small amount of molten metal in these welds at any time. This small amount of molten metal

Table 1. Welding Conditions for Use With the Automatic Pipe-Welding Process.

Pipe wall thickness, in.	5/16	3/8	
Joint design	Square butt	60-deg bevel, 1/16-in. root pass	
Gap width, in.	1/16	1/16	
		Two	
Number of passes	One	Root	Face
Welding wire (highly deoxidized) diam, in.	0.040	0.040	0.040
Voltage	CPRP	CPRP	CPRP[a]
Arc voltage	27-28	27-28[b]	20
Amperage	300	380	210
Travel speed, ipm	44	55	30
Wire feed rate, ipm	560	650	250
Head angle (wire leading head), deg	12	12	12
Shield gas	CO_2	CO_2	CO_2/-argon
Gas flow rate, cfh	30	30	40/10
Costs for wire and gas (per ft of weld)	3¢	6¢	6¢

[a]With welding reactor in series with generator.
[b]29.0 v required to start.

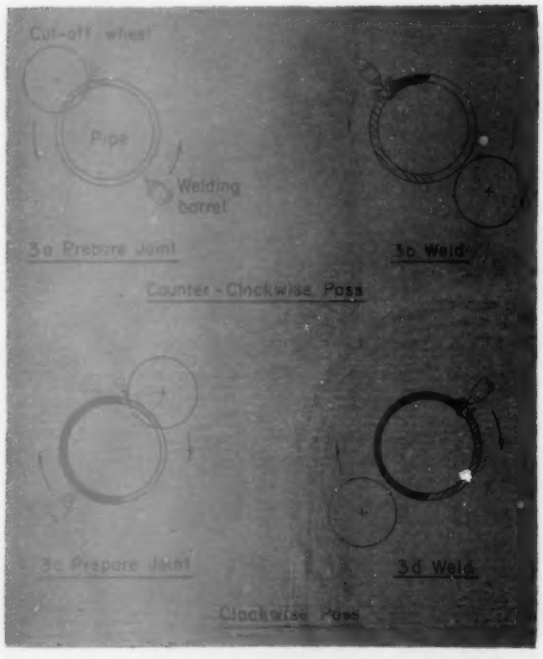


Fig. 3. Sequence of operation for welding fixed-position small-diameter pipe.

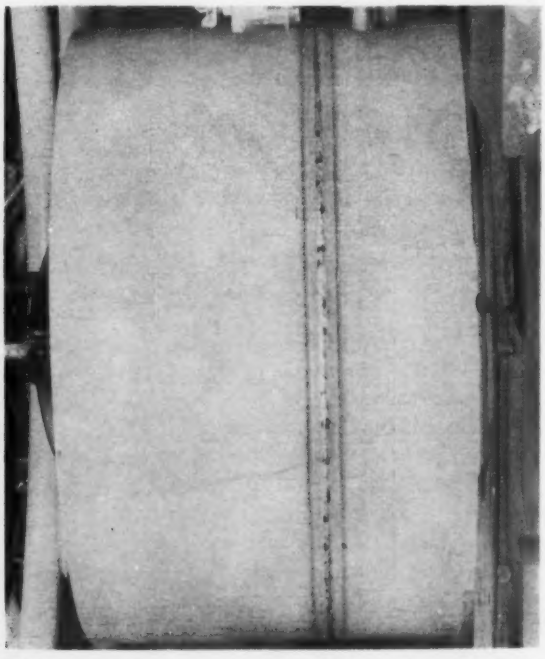


Fig. 4. Completed girth weld in 16-in. diam by 5/16-in. wall T-52 pipe. Dark discolorations are thin manganese-silicate flakes on the weld surface.

and the high cooling rates that are obtained make it possible to produce the weld in all positions around a pipe.

The CO_2-shielded process is readily adapted to welding square-butt joints in pipe. The deep penetrating arc of the CO_2-shielded process easily penetrates and fuses the root of such joints without forming a wide bead. Actually, arcing occurs at about the center of the weld. The superheated molten weld metal flows under the arc to the root and behind the arc to the face of the weld where it melts the upper and lower corners of the joint, resulting in excellent fusion without excessive weld reinforcement.

The weld is made in the downhill direction. By welding in this direction, the molten weld metal flows into the arc due to gravitational forces. The arc forces, however, control the flow of the weld metal so that it does not flow out of the joint or under the arc in sufficient amounts to raise the arc out of the joint and decrease weld penetration to an unsatisfactory condition.

As mentioned previously, the weld geometry represents an optimum relationship between the amount of molten metal in the joint and the arc forces that control the flow of this metal. This relationship is so well controlled in the automatic process that the excellent root fusion and small weld reinforcement, which are important characteristics of the process, are obtained without the use of a weld backup.

Process Variables and Controls

The process has many variables that are accurately controlled to ensure consistent weld quality. These variables are listed in Table 1. Included also are the conditions used to weld pipes with nominal wall thicknesses of 9/32 and 3/8 in.

The joint-preparation operation that is incorporated into the process is used to control root spacing. Accurate control over root spacing is needed to obtain the weld geometry that is required for the single-pass welds and the root pass in multiple-pass welds. Many methods were considered for achieving accurate root spacing, but the method selected is to align and clamp the pipes in preparation for welding and then cut a space between the ends of the pipe with an abrasive cutoff wheel. This method of preparing the joint is extremely accurate, and root spacing is controlled by selecting cutoff wheels of the proper width.

The abrasive cutoff wheels that are used with the process were selected to provide fast cutting rates without the use of a coolant. The cutoff wheels are commercially available in the thicknesses required for the process. The rotational

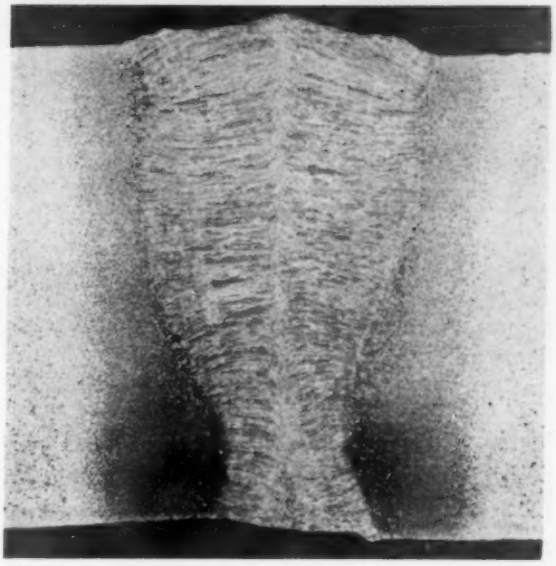


Fig. 5. Macrograph of typical single-pass weld made in 0.280-in. wall pipe.

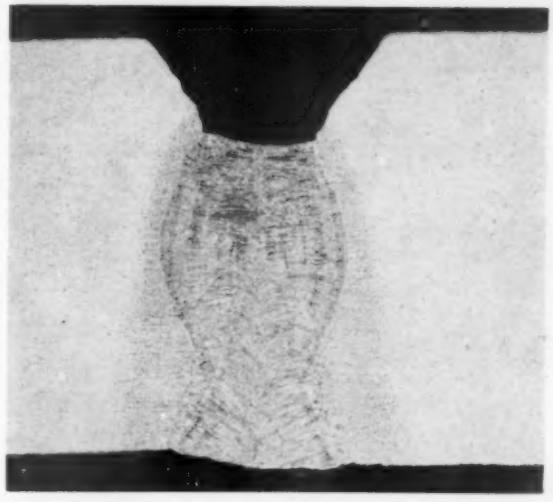
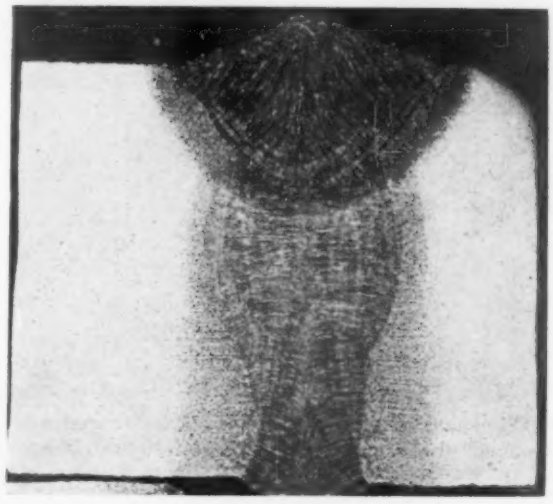


Fig. 6. Weld in heavier wall pipe. Above — Macrograph of first pass. Below — Macrograph of complete 2-pass weld.



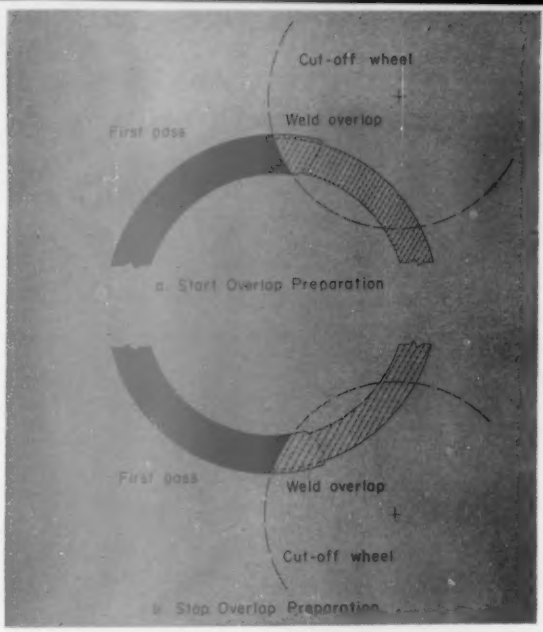


Fig. 7. Weld overlap preparation.

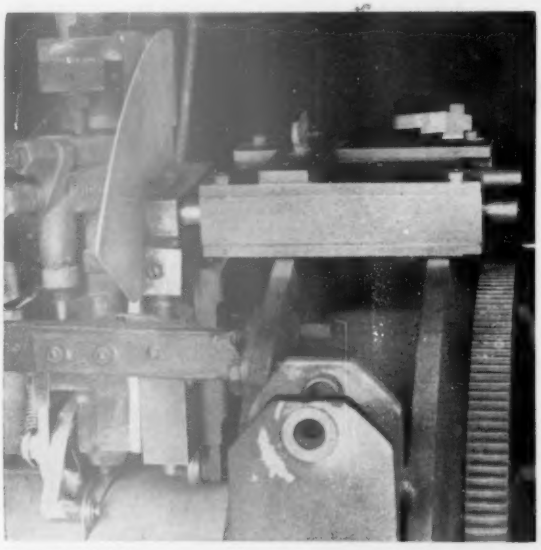


Fig. 8. Welding assembly.

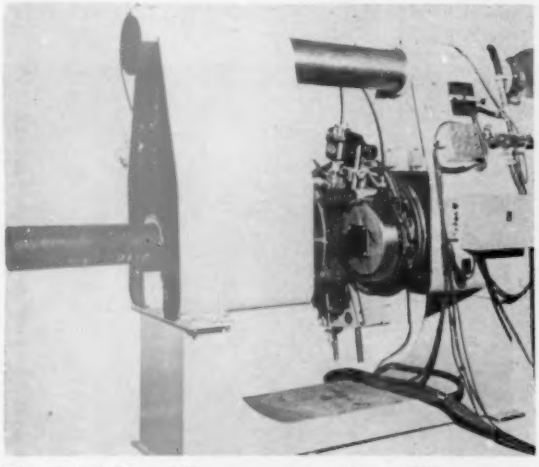


Fig. 9. Field welding apparatus for welding small-diameter pipe. (This photo and Fig. 10 and 11 are by courtesy of Air Reduction Company, Inc.)

speeds of the wheels are set to minimize wheel breakage without sacrificing cutting speed. The joints are prepared at linear speeds up to 55 ipm. Approximately 200 linear in. of joint are prepared with one wheel.

The use of the cutoff wheel to control root spacing in the joint also serves another important function. All welding with the automatic process is done in the downhill direction. Therefore, the weld is made starting at the top and going down one side of the pipe to stop at the bottom. Then, the weld is started again at the top and made down the other side of the pipe to stop a second time at the bottom. By preparing the second side of the joint after the first side is welded, the curvature of the cutoff wheel allows the ends of the first weld to be tapered (Fig.7), thereby promoting excellent weld quality in the area where the ends of the welds overlap.

The joint-preparation operation produces joints with precise root spacings. The welding clamp is important in maintaining the spacing. During welding, contraction of the weld results in forces that tend to pull the edges of the joint together. Therefore, a clamp that resists these forces is required. Satisfactory clamping is achieved with the commercial clamp shown previously.

The joint-preparation operation provides accurate control over joint dimensions. However, the other welding conditions also are accurately controlled to ensure consistent weld quality. The other welding conditions are controlled as follows:

1. Wire-feed speed and weld travel speed, which affect welding current, heat input and weld penetration, are accurately controlled by tachometer feed-back, thyratron-controlled direct-current motors.

2. Contact tube-to-work distance, which affects weld penetration, is kept constant by means of a roller that rides the pipe surface, as shown in Fig. 8.

3. Alignment of the welding wire in the center of the weld joint is maintained with the groove-following device shown in Fig. 8. This is necessary, since wire alignment also affects weld penetration.

4. The proper angle of the welding head is determined by fixed stops on the mounting bracket for the welding head barrel.

Arc voltage is important because it affects the width of the weld, which in turn affects weld penetration. An automatic device for controlling arc voltage and manual control of arc voltage is

used with the process. The characteristics of the welding power source affect arc voltage and weld consistency. A constant-potential, direct-current welding power source is used.

Filler-wire diameter and composition are important. A commercial highly deoxidized filler wire with a diameter of 0.040 in. is used. The highly deoxidized wire is required to minimize any tendency to form porosity in the welds.

Process Equipment Requirements

The success of the automatic process is achieved through accurate control of joint dimensions and welding conditions. The need for these accurate controls imposes important requirements on the equipment that is built for the process.

A prototype machine built for welding 4 to 8-in. diam pipe is shown in Fig. 9. This machine was used to "field test" the process in the oil field of Odessa, Texas.

The most obvious function of the pipe-welding machine is to rotate the joint preparation and welding units around the pipe.

Equipment now available is best described as a rotating ring-type unit. With this equipment, the joint preparation and welding units are attached to a split ring that is rotated around the pipe. The split ring is supported through bearings by the frame of the machine, which is clamped to the pipe. The ring is designed to allow the units to be lifted from the pipe.

Several important requirements are imposed on the rotating equipment by the joint-preparation operation: (1) the equipment must be rigid and rotate the sizing unit in a single plane, (2) the plane of the cutoff wheel and plane of rotation of the equipment must coincide, (3) the plane of the joint must be lined up with the cutoff wheel and plane of rotation, and (4) the sizing operation must be started and stopped at certain locations. All of these requirements are necessary to ensure successful joint preparation. The requirements imposed by the welding operation are: (1) the rotation speed must be accurate, and (2) the welding operation must be started and stopped at certain locations.

The joint preparation and welding units are attached to the rotating ring. Included in the joint-preparation unit are an electric or air motor to rotate the cutoff wheel, an electric motor, hydraulic unit or pneumatic unit to feed the cutoff wheel into or away from the pipe, and microswitches to control the distance that the cutoff wheel is fed into the pipe. The joint-preparation unit on the 4 to 8-in. pipe welding equipment is shown in Fig. 10. Included in the welding

Fig. 10. Cutting unit on small-diameter pipe welding apparatus.

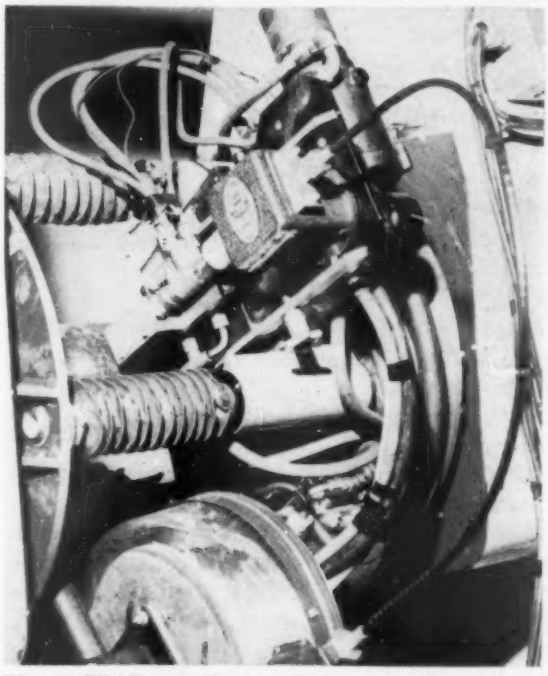


Fig. 11. Welding unit on small-diameter pipe welding apparatus.

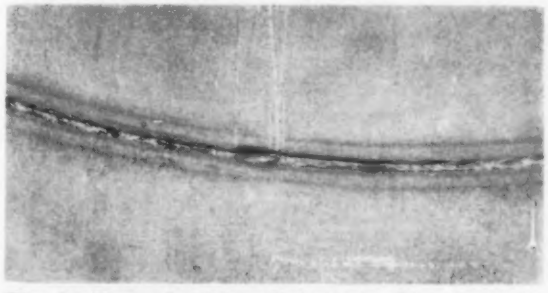


Fig. 12. Root of weld made in 16-in. diam by $\frac{3}{8}$-in. wall pipe. Overlap starts at center of weld. Dark discolorations are thin manganese-silicate flakes on the weld surface.

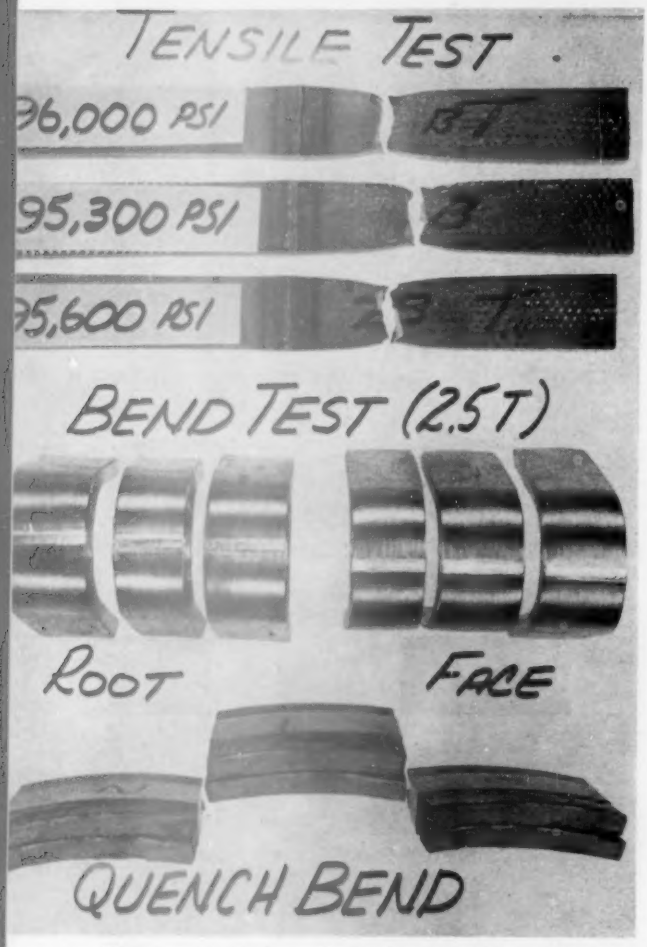


Fig. 13. Typical mechanical tests (16-in. diam by 5/16-in. wall pipe).

unit are a welding nozzle mounted on a floating bracket equipped with a groove-following mechanism and a unit that controls contact tube-to-work distance, a constant-speed wire-drive system that includes a clutch to allow the wire-feed motor to reach speed before wire is fed, a pneumatic or hydraulic system for changing head angle, and a mechanism for moving the welding head into position for welding and retracting it. The welding unit on the 4 to 8-in. pipe welding equipment is shown in Fig. 11.

In welding 16-in. diam and smaller pipe, joint preparation and welding are not done at the same time. Equipment for welding such pipe is made with the welding and joint-preparation units placed 180 deg apart on the rotating mechanism. With this arrangement, the welding unit is in position to start welding when the joint is prepared and vice versa. The welding machine is equipped with microswitches and a control circuit to obtain the proper sequence of operations and to ensure that cutting and welding start and stop at the proper positions around the pipe.

Weld Quality

Visually, welds made with the automatic process differ in contour from manual welds. The face of a single-pass weld is shown in Fig. 4. The faces of these welds are very narrow and are essentially flat with no reinforcement on the top quadrant of the pipe. The faces of two-pass welds in 3/8-in. wall pipe are about twice as wide as the single-pass weld with uniform weld reinforcement in all positions around the pipe.

The roots of single and multipass welds are similar in appearance to the roots of manual welds, except that the reinforcement is slightly lower in the vertical welding position and uniformity is much better than for manual welds. A typical weld root is shown in Fig. 12.

Mechanical properties of welds made with the automatic process are satisfactory and meet the usual requirements for pipeline welding. Tensile test specimens fail in the base metal with and without weld reinforcements. Most bend specimens are successfully bent around a radius of less than two times their thickness, even welds in pipe having yield strengths over 52,000 psi. Normally, welds in such pipe are considered satisfactory by code requirements, if they can be bent around radii of 4 times their thickness. In addition, nick-break specimens, which are intentionally notched in the weld to direct the failure to that point, do not fail in the weld-metal zone. A special bend test in which the specimens are quenched from temperatures above the upper critical temperature is required to cause failure in the weld metal. Typical tensile and bend specimens are shown in Fig. 13.

Sound welds that readily pass radiographic specifications also are obtained. The use of improper filler wire, however, will result in excessive porosity.

Acknowledgment

The authors wish to express their appreciation for the technical assistance offered by M. J. Dabney and M. F. Sheely of Esso Research and Engineering Company. Acknowledgment also is due F. A. DeSaw of Battelle, who assisted in the development of the welding process in many ways. Furthermore, the assistance of the Air Reduction Company in making available Fig. 9, 10 and 11 is gratefully acknowledged.

Three of the authors are with the Metals Joining Division, Battelle Memorial Institute, Columbus, Ohio, as follows: J. W. Nelson as principal welding engineer, G. E. Faulkner as assistant chief, and P. J. Rieppel as chief. H. C. Cook is assistant pipeline manger, Esso Research and Engineering Company, Elizabeth, New Jersey.

Based on a paper presented at American Welding Society's annual meeting, New York, N. Y.

■

by Frank H. Love

Regular Maintenance Cuts Breakdowns

A planned program of maintenance and repairs is paying dividends for a large Houston-based pipeline contracting firm by reducing major breakdowns on jobs in progress and improving job continuity. The program to keep equipment in good condition includes, with some limitations:

1. A complete spread overhaul following each construction year.

2. A specific basis for determining when equipment should be traded or otherwise disposed of.

3. Insistence that necessary minor equipment repairs occurring during the course of a job be made immediately.

Where to Overhaul

Once it has been decided to overhaul a spread, there are two possible locations for performing this work: site of the just-completed job, or location where the equipment will be used next. Deciding factors are availability of parts and machine shop facilities, adequate enclosures or building within which to perform the overhaul, comparative climatic conditions and attractiveness of other services.

At end of the work season all equipment is generally stacked in the vicinity of its last job, except that sent to the central warehouse in Houston. Normal demobilization practices are followed, such as draining and tagging all radiators, checking any final drives for water, rainproofing exhaust stacks, etc. Equipment returned to the central warehouse includes welding machines, dope kettles and truck tractors requiring major overhaul and specialties such as beveling machines, line-up clamps, cradles, calipers, air compressors and water pumps. These items are then available in a central equipment pool to be assigned to future jobs.

Also sent to the warehouse, but contingent upon geographical distances, are trucks, and in some instances tractors, backhoes and dozers, that are to be stripped and disposed of by trade or sale.

Within the general framework of this policy, what is to be repaired in the field or sent to the warehouse is determined by an evaluation by the spread master mechanic, approved by the spread superintendent.

Repair Cost Estimate

Before beginning a spread overhaul, an estimate is made of the repair cost for the entire spread. The spread master mechanic fills in an equipment repair form for each large piece of equipment—ditching machines, backhoes, tractors, bending machines, cleaning machines, etc., — but not for tools and miscellaneous small items (see Fig. 1). This same form also is used for equipment considered ready to trade or sell.

These recommendations are checked at the Houston warehouse by the company's chief engineer and mechanical superintendent, and an estimate made of cost of the suggested repairs, considering both labor and parts.

After repair cost of major items is totaled, a reasonable amount is added for miscellaneous small items not covered by the equipment repair forms. This provides a target figure for the

EQUIPMENT REPAIR FORM

DATE

MACHINE

MODEL

SERIAL NO.

COMPANY NO.

FROM JOB NO.

DATE TRANSFERRED

TO JOB NO.

WORKING CONDITIONS

MACHINE OPERATOR

JOB MECHANIC

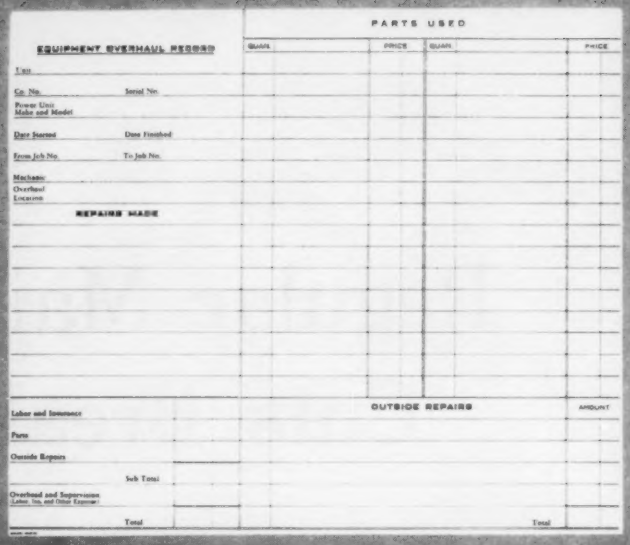
REPAIRS TO BE MADE

SIGNATURES OF

SUPERINTENDENT

MECHANIC

FIG. 1. This form is filled in for each large piece of equipment to be repaired, and also for equipment considered ready for trade or sell.



EQUIPMENT OVERHAUL RECORD

PARTS USED

QUAN. | PRICE | QUAN. | PRICE

Unit

Co. No. Serial No.

Power Unit Make and Model

Date Started Date Finished

From Job No. To Job No.

Mechanic

Overhaul Location

REPAIRS MADE

OUTSIDE REPAIRS | AMOUNT

Labor and Insurance

Parts

Outside Repairs

Sub Total

Overhead and Supervision (Labor, Ins. and Other Expense)

Total

Total

FIG. 2. Upon completion of an overhaul, a cost record like this is prepared for each major unit of equipment.

overhaul crew and a means of exercising cost control. However, it is flexible for revision should the estimate prove too far out of line.

When to Retire Equipment

When should a piece of equipment be traded or sold? There is no "rule of thumb," but each piece of equipment is evaluated on its own merits. Age of unit and current cost to put it back in good operating order are obviously important. Other factors are:

1. Historical maintenance cost of the unit. A permanent record of annual overhaul cost of each unit is maintained. ("Lemons" are as prevalent among tractors as among automobiles.)

2. Obsolescence of the unit by comparison with current models (horsepower, capacity, speed, mechanical improvements, etc.).

3. Type of unit. (A dozer reaches its economical trading age almost twice as quickly as a large sideboom tractor.)

Field Overhaul Crew

Field overhaul crew necessary to overhaul a good size main line construction spread of equipment is composed of 20 to 24 men minimum and 32 to 36 maximum. This is broken down into smaller crews, generally of one mechanic and one or two helpers.

Three crews are used on sidebooms, dozers and tow tractors; one or two crews on draglines-backhoes; one on ditching machines; one on trucks, and one for repair of miscellaneous equipment such as gasoline engines, welding machines, water pumps, saws and light plants.

In addition, there are one or two welders to build up tractor rails and rollers, dragline sprockets and tumblers and other miscellaneous fabrication, plus three workmen to wash and steam-clean the equipment and repaint after overhaul. A parts buyer, office man, and "boss man" complete the organization.

Some work, such as radiator repairs, vehicle glazing, machine shop work, armature rewinding, etc., is subbed to service companies.

Upon completion of the overhaul, an overhaul cost record is prepared on all items in the overhaul. One copy of the record remains with the spread and one is kept in the warehouse files (see Fig. 2).

Central Warehouse

The central warehouse in Houston serves several purposes. Here are built the drawworks, booms and backfill buckets for backfill tractors. Replacement parts for backfillers are also made and kept in stock. Here, too, the tack tractor used for hot pass welds as well as the stringer bead is assembled.

The tack tractor is shown in Fig. 3. The tractor, which in this case is an International Harvester TD-18 (sometimes it is a TD-20), has mounted on it two Lincoln twin-arc welding

FIG. 3. "Tack Tractor," used for making stringer bead and hot pass welds, is assembled at contractor's central warehouse.

FIG. 4. Backfiller is another piece of equipment fabricated and assembled by the contractor whose work included building the drawworks for boom hoisting, bucket casting and bucket crowd.

generators, providing a total of four 300-amp, 40-V welding leads. Power to drive the welding generators is taken off the front of the engine shaft through the standard IH power takeoff. Generators are driven by a high-velocity, oil-submerged, chain drive mounted on a wishbone frame on the front of the tractor. There is 1% speed control on the engine governor to minimize voltage fluctuations caused by changes in engine speed. Normal speed control is 4%.

The backfiller attachment is shown in Fig. 4. In this photo the attachment is mounted on a Caterpillar D-7 tractor. Fabrication and all work necessary to build the drawworks for boom hoisting, bucket casting and bucket crowd is performed at the Houston warehouse.

When new trucks are brought into the fleet, certain parts must be added to equip them for specialized pipeline construction service — gin poles, bed, headache rack, winch, power takeoff, and heavy duty front bumper. The average life of a truck is about four years. Only the ones to be traded or sold are brought into the warehouse, where they are first stripped of the above specialized equipment.

Heavy diesel truck tractors, requiring extensive overhaul work, are usually brought to the warehouse. All other trucks are repaired in the field as part of the spread overhaul. Here is a typical repair history of an average winch truck or pickup truck:

First season — Grind engine valves; install new piston rings; overhaul brakes and clutch.

Second season — Bore block and put in oversize pistons and rings; grind valves; overhaul clutch, brakes and transmission.

Third season — Install new "short" block with basic assembly; again overhaul brakes and clutch.

Fourth season — New rings; valve job; overhaul brake, clutch and transmission.

Another policy that pays off is to keep the same equipment with a spread. Intermixing is done only in unusual circumstances, which stem primarily from mobilization expedients. This policy serves two purposes: responsibility can be placed for the condition of the equipment, and the spread knows the limitations of each unit and can use it where it will give the best service.

The planned program for reducing major breakdowns on the job has proved highly successful. Minor repairs are bound to be needed, of course, and on each heavy spread there are two master mechanics with their helpers and a truck mechanic and his helper.

Detailed records are not required for mechanical maintenance performed while a job is in progress. But management does insist that equipment be given the best of care — changing oil of the right type and grade and filter cartridges at regular intervals, greasing often, etc., — and, as previously mentioned, making small repairs before they necessitate big repairs.

Regarding the latter, the company's chief engineer points out "Simple maintenance accomplished at the right time will save money in the long run." To elaborate, an inexpensive but badly worn bushing can, under continued operation, damage the shaft and bushing hub. What at one time was a $50 repair bill can become a $500 repair bill. ■

Gas from Gulf Oil Corporation's cycling plant (background) will heat homes and businesses in western Great Lakes region.

The 24-in. spur line, shown in completion stages (foreground), ties 24 miles away to American Louisiana's northbound main line.

"Chloe" Pipeline Laid in Louisiana

An "island" and timber mats helped solve the complicated construction of a pipeline through Louisiana swampland.

The line is a 4-mile watery segment linking American Louisiana Pipe Line Company's main system with Gulf Oil Corporation's Krotz Springs cycling plant, St. Landry Parish.

Through the West Atchafalaya Floodway, 35 miles west of Baton Rouge, it is the final part of a 24-mile section to take 50 MMcf of gas daily into the pipeline system which serves the upper Midwest area.

Dry gas from which the liquid hydrocarbons have been extracted is destined for heating and industrial use in the Western Great Lakes Region.

Crews fabricated the line on an "island" prepared as a construction pad and launching ramp. Steel drums were secured to the cement-coated pipe and the line floated into the trench as each joint was welded on.

Tractor, pushing from the ramp, and spud-barges, pulling and guiding the plugged nose of the line, snaked it through the water and across the swamp. The push and pull efforts were coordinated with the use of walkie-talkie radio.

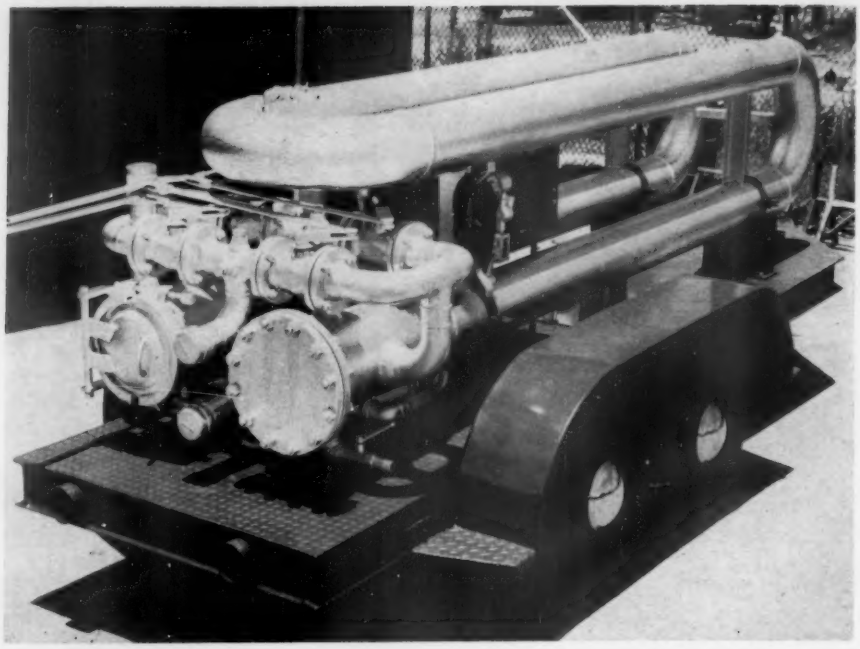
One section was pushed 4000 ft eastward to connect with pipe on dry land near the Gulf plant. The other section was tugged and shoved 16,000 ft westward to connect with pipe already laid to the floodway levee.

After the line was in place, the floats were cut free, permitting it to settle to the trench bed, which was backfilled later.

Ford, Bacon and Davis Construction Corp., prime contractor on the job, laid the dry land portions of the line.

■

Barrel-borne pipeline, shoved into water-filled trench from launching ramp, was floated across swamp.



Trailer-mounted model of bidirectional continuous flow meter prover stresses maximum mobility for high-speed highway transportation and rugged off-the-road service and is particularly suitable for LACT installation meter proving.

Running-Basis Meter Proving

Running-basis proving of positive displacement and turbine meters has forged past the experimental stage and penetrated a good distance into the operational picture.

Making this possible is development of a meter prover unit that consists basically of a calibrated pipe section teamed with electronic digital counting equipment.

These units are now in use in applications ranging from lease automatic custody transfer to extremely high flow rate liquids pipelining.

Greater use of larger capacity meters, resulting from increased pipeline automation, wide diversity of liquids being transported, and mushrooming of LACT installations, had enhanced the need for periodically proving meter accuracy in a practical, economical manner. This extends as well to the growing number of smaller capacity meters in lease automatic custody transfer operations.

Advances in meter proving have come so fast the API Committee on Liquid Metering already is considering a supplement to the 1960 revision of API Standard 1101 on High Speed Meter Provers.

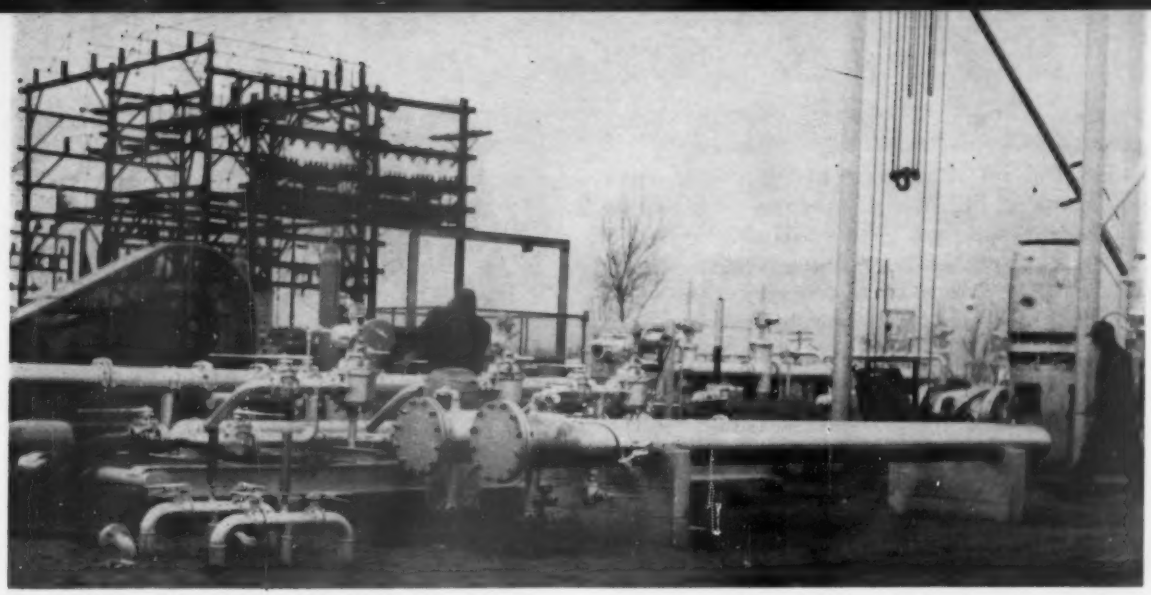
Provers Are Flexible

Extremely flexible and adaptable, the new generation of meter provers can be either semi-permanent, permanently installed, or highly portable. They can be built either for 1-way (unidirectional) or 2-way (bidirectional) liquid displacement.

Design of both the unidirectional and bidirectional provers permits the stream to move through the prover whether the proving procedure is under way or not. Thus interruption of continuous meter measurement is avoided.

All variations of such systems are based on the principle of accurately displacing a known volume of fluid between two measuring points with a piston device in a cylindrical container.

Basic components of a high-speed mechani-



U-bend bidirectional continuous flowmeter prover permanently installed at Shell Pipe Line Corp. facility near Wink, Texas. This system has a 150-gal prover volume and is fabricated with 8-in. pipe.

cal displacement meter prover consist of the proving section (a portion of the pipe accurately calibrated volumetrically), manifolding and valving to direct the liquid flow through the prover, and high-resolution electronic circuits to permit direct comparison between the meter reading and actual liquid volume throughput.

With electronic equipment it is possible to prove meters on a "running" basis using a volume less than that considered minimum for previous methods of meter proving.

Also, with the continuous flow basis method, the meter measures the same quantity of fluid per revolution with identical performance during both proving and normal operations.

Therefore, volumes as high as 36,000 gal per hr can be proved accurately, for example, with a prover section capacity as small as 180 gal.

Electronic circuitry consists of a tachometer or pulse transmitting device attached mechanically to the output shafting of the meter (sometimes as a separate unit and sometimes as an integral part of the meter); a gate to actuate and deactivate a counter (again, either separate or as a device built into the counter), and an electronic counter.

For proving purposes, only those impulses transmitted during the proving run are counted. Sensing devices or detectors, activated by the piston, actuate the counter at the start and stop limits of the calibrated prover section.

How Prover Developed

The true beginnings of continuous flow meter proving date back to use of a measured part of an actual pipeline as, in effect, a calibrated known-volume prover section—either as a non-return type (measured mile) or return type (endless loop).

Shell Oil Company and Shell Pipe Line Corporation have done important research and experimental work along these lines for several years. Associated with Shell in this development is the F. H. Maloney Company, a Houston engineering and manufacturing firm which presently is sole producer of the rubber spheres that form an integral part of "running" basis meter prover units.

Shell researchers, seeking improved methods of batch separation in products lines, adopted the rubber sphere for a variety of pipelining tasks including purging and cleaning operations. Eventually it was assigned a new role as the piston in meter prover sections of pipelines and other mechanical displacement-type meter prover units.

These units are now manufactured by Maloney in a wide range of sizes, capacities, and types under license agreement from Shell Development Company.

Elements of the Meter Prover

These high-speed, positive displacement meter provers have the following elements: a prover section of pipe with a configuration suitable for the type of work intended, nature of the installation and the space available; two Mark IV Sphere Here Detector sensing elements placed at the start and stop points of the prover section; a tachometer or other type of pulse generator located at the meter, and an electronic counter.

The Mark IV Detector, which acts through an electronic gate to actuate the counter, has

an accuracy range of one count in 4000 counts per second.

The counter is accurate to within one count in a range of operations from one cycle per sec to 120,000 cycles per sec.

The tachometer or pulse generator has a speed range of zero to 10,000 rpm, although it normally operates far below this maximum.

The Way It Works

In all applications — unidirectional, bidirectional, permanent installation or portable unit —the proving operation works this way:

The stream passing through the meter is diverted through the prover, except in onstream proving when a section of the pipeline itself is the prover section and no diversion is necessary. The prover is so designed that the stream bypasses the rubber sphere piston with no restriction to flow.

The piston is launched into the stream in one manner or another, depending upon the type of prover involved, and as it passes the first Mark IV Detector, it contacts the detector's probe. This actuates a switch, energizing the electronic counter.

The piston travels at the flow rate of the stream through the length of the prover section until it contacts the probe of the second Mark IV Detector, which then trips the gate, stopping the pulse count.

For a bidirectional prover, the procedure is repeated in the opposite direction to complete the run.

Pulses recorded by the electronic counter represent the total volume of liquid measured by the meter while the piston is displacing the liquid in the prover section of the system.

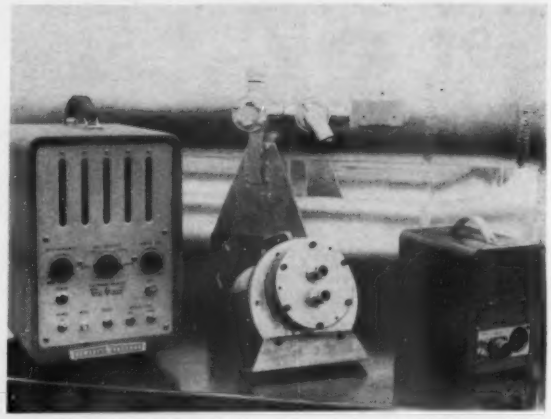
The relationship between the prover section's known volume and the registration of the meter during the run is represented by the formula:

$$\text{Meter Factor} = \frac{\text{Prover Volume} \times \frac{\text{Prover Temp. Cor. Factor (liquid)}}{\text{Press. Cor. Factor}} \times \frac{\text{Prover Temp. Cor. Factor (Steel)}}{\text{Compression Cor. Factor}} \times}{\text{Meter registration} \times \text{Meter temperature Correction factor (Liquid)}}$$

Therefore, the total pulses counted during the run, corrected for temperature and pressure conditions, permit calculation of the meter factor.

Calibration of the meter provers may be done at the factory or in the field by either the water withdrawal or master meter method.

Of the two, the water withdrawal procedure is used predominately. A quick-closing type of valve on the discharge side of the meter prover and a relatively low pressure water source are employed. As the sphere piston travels through the prover section, water is withdrawn into calibrated containers with seraphin type (restricted) necks. This permits a highly accurate volume measurement.



Components of the electronic system in the continuous flow meter prover are the high speed digital counter, the tachometer (pulse transmitter), the electronic gate and (mounted above the gate) the Mark IV Sphere Here Detector.

For the master meter test, an accurately calibrated meter is used with the prover hooked up to it. The prover count is compared to the meter-measured total during test runs. With this method, it is considered desirable to use a light oil as the testing medium to insure better meter functioning and sphere piston performance.

Both methods are certified to .02% during factory calibration, satisfying API Code 1101 and its supplements.

Unidirectional Provers

The range of unidirectional meter provers now in production by Maloney include both permanent, non-return type onstream proving installations, utilizing a section of pipeline, and permanent-type, closed-loop provers. In the second type, an automated interchange unit is tied into the loop as a control unit and piston launching and recovery mechanism. The unit utilizes a Maloney/Cameron ball valve, adapted for 180-deg rotation and equipped with a 90-deg side outlet. When the launch button is punched, the valve automatically rotates, drops the sphere into the stream, and dwells for a pre-set time to permit the sphere's completing the proving run. The sphere is removed from the stream in an over-sized separator tee and drops by force of gravity back into the valve cavity in position for re-launching. For removal or replacement of the sphere, an unload button is pushed, causing the valve to rotate 90 deg and stop. The ball can then be removed and replaced through a quick-action closure on a side outlet connection. Pressing a return but-

ton causes the valve to rotate back to its normal position.

This permanently installed closed-loop type prover may be mounted above or below ground as a field installation. A prefabricated loop section and interchange assembly also is available as a complete unit—tested, calibrated, and ready for shipment. The loop assembly may be installed vertically or horizontally.

For these types of units, there is no practical mechanical limitation on size or flow rate. Cost, however, imposes economic considerations with increasing volume, pressure, etc.

Standard factory-complete units range from a pipe size of 8 in. with a prover volume of 160 gal designed for a maximum flow rate of 750 bbl per hr, up to 16-in. pipe size with 40-bbl prover volume designed for a maximum flow rate of 7600 bbl per hr.

Bidirectional Meter Provers

In the bidirectional field there are both portable and permanently installed types of meter provers.

By a valve and manifolding arrangement, the stream from the meter is passed through the prover, first in one direction, then in the other. As the sphere piston travels each way, it actuates the electronic circuitry so that a counter reading is obtained for both trips to make a complete run.

Bidirectional provers are particularly suited for portable and semipermanent installations and also offer compact design for permanent installations where space is limited. Although they can be designed for use with larger meters, the bidirectional version is especially useful in proving meters in the 2-in. through 6-in. size range.

Standard models of portable, bidirectional meter provers are in two sizes—both in the ASA Series 300 class with maximum operating pressures of 720 psig. Pipe size for prover loops in both models is 8-in.

One of the units, designed particularly for 2-in. meter use, has a 43-gal prover volume with a maximum flow rate of 140 gal per min.

Intended for use in the 3-in. meter catagory, the other has a 105-gal capacity and can handle a maximum flow rate of 350 gal per min.

The units are both skid and trailer mounted.

LACT Procedure

In LACT work, field results so far indicate it is not unusual for a single operator to hook up a trailer-mounted unit, prove the meter, uncouple and depart for the next location within 15 to 20 min after arrival at the site.

On a typical trailer-mounted bidirectional unit there is a 3-valve manifold—the incoming supply valve, the outgoing or discharge valve, and the block valve. On the input and discharge valves are 3-in. quick connect couplings, matching couplings on two 3-in. hoses.

For proving a LACT installation, the unit is positioned next to the meter-proving connection and tied in through the hoses. Inlet and discharge valves are opened, prover checked to insure proper alignment of the valves, and the block valve is shut, forcing oil from the meter unit into the prover.

Temperature of the fluid at the meter and the prover is equalized by flowing it for several minutes through the unit (the temperature is checked at the input and discharge valves), and electrical connections are made up.

To begin the proving operation, the manifold is reversed, changing the direction of flow through the prover section. The sphere piston moves into the prover section, traveling at the same rate as that of the fluid passing through the meter.

Following normal bidirectional proving procedure, the flow is reversed again, and the total counts for the two passes converted into gallons are compared to the meter-recorded volume.

A satisfactory proving run consists of two consecutive tests that are within 0.05 of 1% of each other, with the average of the two runs establishing the meter factor.

Valves and equipment are then returned to their original state, and the unit is ready for service at another location.

U-Bend Design

For a permanent installation of the bidirectional type, a meter prover of U-bend design can be built in any series of flanges and valves to attain any feasible maximum flow rate, although these units also can be used to prove smaller capacity meters.

The U-bend design, besides being a space-saver has the advantages of the controls and originating and receiving points for the piston being located close to each other. Because of its doubled-up nature, this type of system also operates with smaller diameter pipe for the same volume compared with a linear unit. Connecting lines are shorter and pressure drop is less.

Perhaps the most striking feature of these meter provers is the speed of operation. Meters now are proved in minutes, instead of hours. There are no stop-start surges. The meter stays in service while being checked, eliminating need for "simulated conditions."

■

Dust in Gas Streams

by Arnold W. Doyle, Norman M. Wiederhorn and Arthur Swan

IN sampling a suspensoid flowing in pipe, a representative sample must be drawn to the instrument, generally located outside of the line, through a sampling probe which, no matter how well designed, has flow characteristics that introduce errors in particulate determination.

This chapter discusses the type of errors introduced and recommends procedures that will minimize them.

Numerous sampling procedures are employed by the various companies within the American Gas Association. These companies are accumulating information on standardized equipment. If data taken with this equipment is to be directly comparable, sampling procedures must also be standardized whenever possible and any inherent errors understood. In any gas-sampling system there are several possible sources of error. These are illustrated in Fig. 1, which depicts a generalized sampling arrangement.

The major sources of error occur:

A. At the entrance to the sampling nozzle, where the linear velocity may differ from that of the line. This may cause an increase or decrease in the concentration of particles being sampled.

B. At bends in the sampling line, where impaction and subsequent loss of particles may occur.

C. At the walls of the sampling probe, where losses by diffusion of the particles may occur.

D. In vertical sections of the tubing, where the velocity may be insufficient to support the particle.

E. In horizontal sections of the tubing, where particles may settle.

F. Because of the introduction of spurious liquid particles, due to the cooling or heating that accompanies expansion or compression of the gas within the sampling system.

G. Because of the diameter of the probe nozzle.

If the best possible sample is to be drawn, it is essential that these factors and their effects be thoroughly understood.

Sources of Errors Sampling

When a sample is withdrawn through a nozzle from a fluid stream at a rate such that the linear velocity through the aperture of the nozzle is equal to that in the fluid stream, the sample is said to be withdrawn isokinetically. Numerous investigators[1,2,3,4] have found that isokinetic sampling is required to obtain a representative sample of the material in the stream.

The need for isokinetic sampling is illustrated

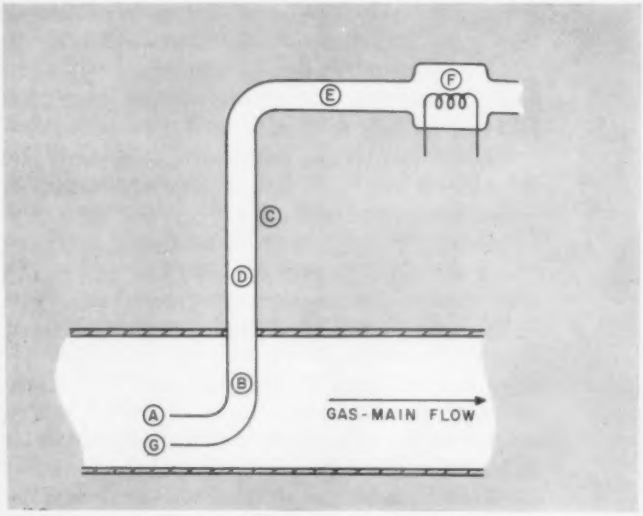


Fig. 1. Possible sources of error in a typical sampling system.

in Fig. 2, which shows several air flow patterns. In Fig. 2-A, the sample is drawn through the aperture of the sampling nozzle at a velocity that is greater than the velocity of the gas in the stream. The gas sample, therefore, is drawn into the nozzle, causing the flow lines in the main stream to converge toward the nozzle.

Under such conditions, a collection will not contain the proper number of large particles. The large particles, because of their greater inertia, will tend to travel in a straight line. Consequently, such particles will not follow the flow lines into the nozzle, but will tend to cut across them and continue downstream of the sampling point. On the other hand, the smaller particles, because of their lesser kinetic energy and inertia, will follow the flow lines and will be collected in a representative manner.

Fig. 2-B shows the sample being withdrawn at a rate where the velocity through the aperture of the sampling nozzle is appreciably less than that in the main stream. The flow lines in the gas stream diverge around the sampling nozzle. Again, the small particles will follow the flow lines, while the large particles will tend to cut through them. In this particular case, however, a traversal of the flow lines by large particles will cause too many to enter the face of the sampling nozzle. As a result, the sample will contain an excessive number of large particles.

Fig. 2-C depicts isokinetic sampling. It may be seen qualitatively that, under these conditions, a representative sample should be removed from the flowing stream.

The configuration shown in Fig. 2 is for the case where the sampling nozzle is parallel to the lines of flow. In practice, probes are quite often introduced normal to the lines of flow. Obviously in such cases when the velocity through the aperture of the sample is equal to that of the gas stream the sampling cannot be considered as isokinetic. Large particles will not be drawn into the probe and the errors introduced will depend on the size of the particles.

In the remarks above, reference has been made quite loosely to the terms "large" and "small" particles. For practical purposes, any particle two microns or less in diameter may be considered *small*. This statement is based upon the work of Watson,[4] who calculated the curves illustrated in Fig. 3 for spheres of unit density. These curves indicate that, under most sampling conditions, appreciable errors in concentration are not encountered when the particles are less than four microns in diameter.

True isokinetic sampling also requires laminar flow. When turbulent flow is encountered, the qualitative arguments described above are not necessarily applicable. General practice, however, has been to consider sampling as isokinetic whenever the forward velocity through the aperture of the nozzle is the same as the average forward velocity of the gas in the pipe. In most situations the flow in gas distribution and transmission systems is highly turbulent. Although in theory laminar flow conditions are necessary, there is evidence that a representative sample can be obtained even when the flow is turbulent.[5] In either case, it is desirable to sample isokinetically. If conditions prohibit isokinetic sampling, then the approximate error can be calculated from Fig. 3, and the results corrected.

Bends In The Sampling Probe

When a particle in a flowing stream is swept around a tube, two forces are present that do

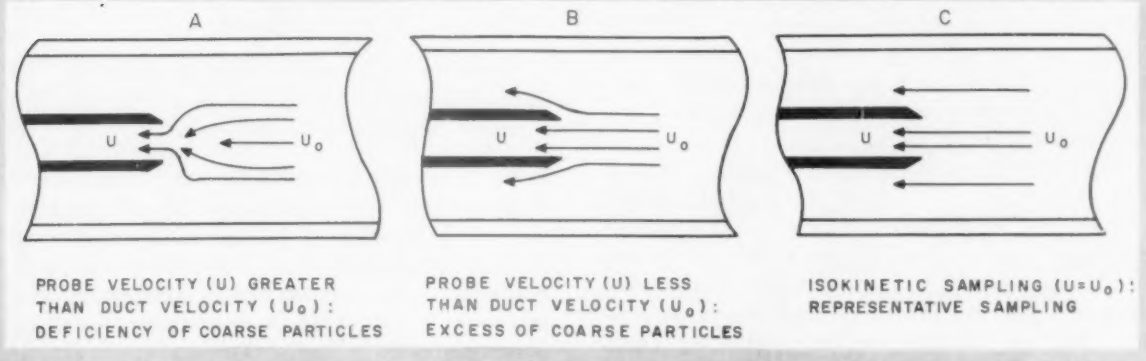


Fig. 2. Errors due to non-isokinetic sampling.

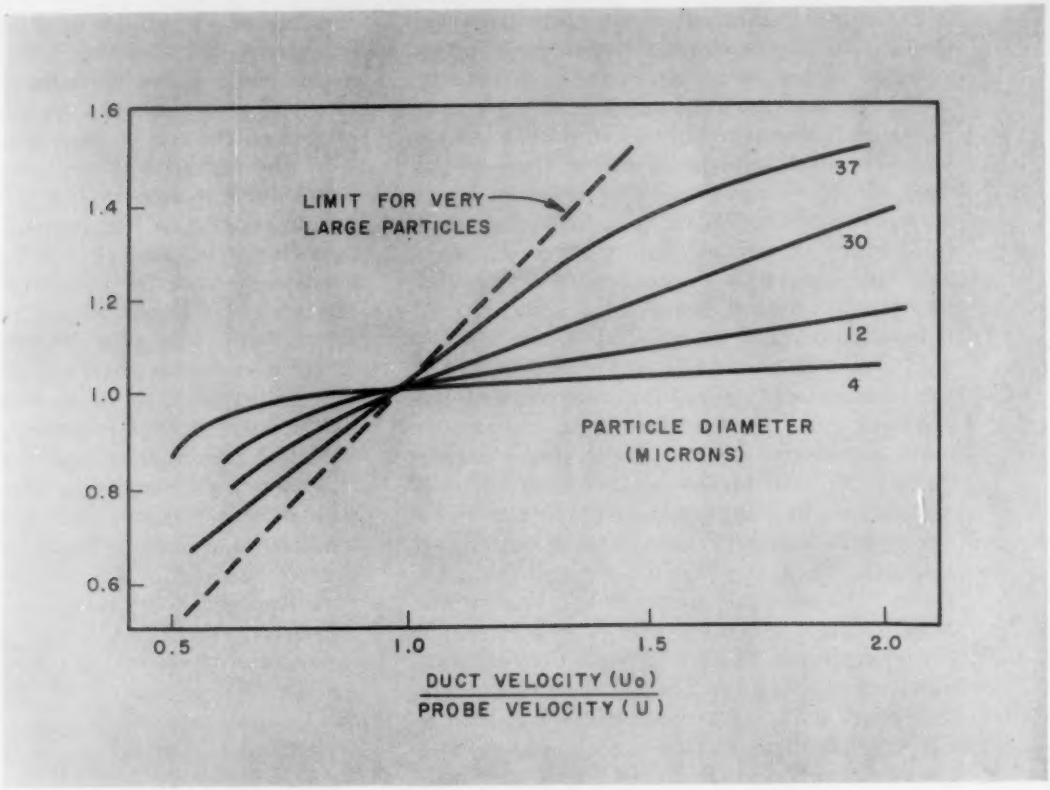


Fig. 3. Effect of non-isokinetic sampling for various size particles based on data of H. H. Watson.

not exist when the particle is moving in a straight section of pipe. These are due to (1) viscous drag by the medium in which the particle is moving, and (2) the centrifugal effects in negotiating the turn.

Fig. 4 illustrates the motion of a particle in the fluid stream. The dotted line is the path of the gas, assuming no pressure gradient due to the centrifugal action. The solid line represents the motion of the particle under the influence of the existing forces. Radial forces resulting from the centrifugation and drag exist only in the turn. However, the sideways motion of the particle in the stream continues after the particle has left the bend and is traveling in the straight section of pipe.

The lateral motion of a particle at a turn in the stream is a source of error in sampling probes that have bends, since impaction of the particles on the wall of the probe can occur with a consequent loss of particles. It is desirable to know the extent of such losses. A precise solution of the problem would be long, requiring the use of high speed computers. The problem is greatly simplified by considering the bend to be one-fourth of a revolution of a centrifugal separator. Equations of motion of a particle in a centrifugal separator have been worked out[5] and using these expressions[5]

$$D_p = \left\{ 9\mu \frac{ED}{V(\rho - \rho_o)} \right\}^{\frac{1}{2}}, \quad E = \frac{V(\rho - \rho_o) D_p^2}{9\mu D} \quad . \quad (1)$$

Where E is the fraction of the particles of diameter D_p that will impact against the wall of the bend if the gas is moving with a velocity V in a pipe whose diameter is D. μ is the viscosity of the fluid ρ and ρ_o are the densities of the particle and fluid respectively.

A similar expression may be obtained by assuming that the particles reach the wall by a simple impaction phenomenon.[5]

Eq. 1 is only a reasonable semi-quantitative description of what occurs at a turn in the pipe, since it does not consider turbulent effects. On the basis of this expression, however, it is possible to draw a number of interesting and important conclusions concerning sampling errors at bends in probes. These are:

1. As a velocity in the probe increases a greater fraction of the particles will impact against the walls.

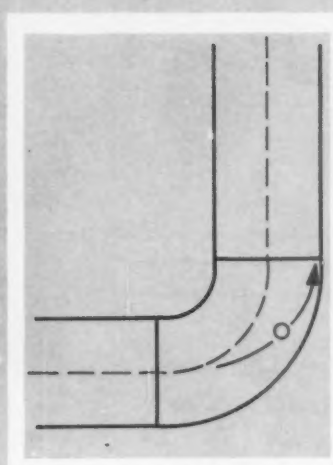


Fig. 4. Particle motion in a bend of pipe.

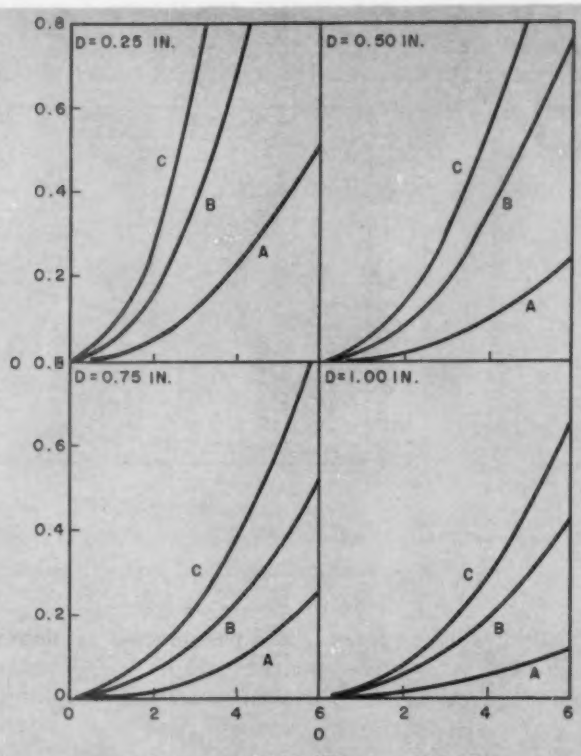


Fig. 5. Fraction of particles impacting at a single 90 deg bend in various size probes and at various gas velocities. Charts are calculated for spherical particles of density 2 in methane at 14.7 psig.

2. Impaction will be greater for larger and more dense particles.

3. The fraction of particles reaching the walls of the probe will decrease with increasing probe diameter and with increasing gas viscosity and density.

If it is assumed that all the particles that impact against the walls of the probe will adhere to the wall, then E in Eq. 1 is the fraction of particles of diameter D_p that are lost at a bend. Under certain conditions this fraction may be considerable. This is illustrated in Fig. 5, where curves are presented for the fraction of the particles that will impact against the wall of a probe as *a function of particle diameter, probe diameter, and gas velocity in the probe.*

Here it may be seen that very appreciable losses may be expected for particles with diameters greater than two to four microns under conditions that are prevalent in most sampling situations.

Actually, the situation depicted in Fig. 5 is probably overpessimistic, since it assumes that all particles that impact on the wall adhere to it. This certainly will not be the situation for a dry dust, as many of the particles will be re-entrained in the gas stream. The situation, nevertheless, is quite serious and in model experiments appreciable losses due to this phenomenon have been demonstrated.[8]

Where more than one bend is present losses will occur at each bend. The total loss (E_T) may be obtained from the following expression:

$$E_T = 1 - (1 - E)^n \quad . \quad . \quad . \quad (2)$$

where E is the fraction lost at each bend and n is the number of bends. Thus the losses increase exponentially with the number of bends.

The seriousness of this situation can be illustrated by a simple example. Consider a 1.0 in. probe with a sampling velocity of 20 mph and 3 bends. For 5 micron particles, Eq. 1 or Fig. 5 indicates that $E = 0.22$ or 22% of the suspended particles will be lost at each bend. From Eq. 2, $E_T = 0.53$ or 53% of the 5 micron particles will impact against the wall. The losses will be even greater for the larger particles.

Diffusion Of Particles

Diffusion of particles to the probe wall could be caused by several mechanisms; Brownian motion, turbulence, electrostatic forces, and

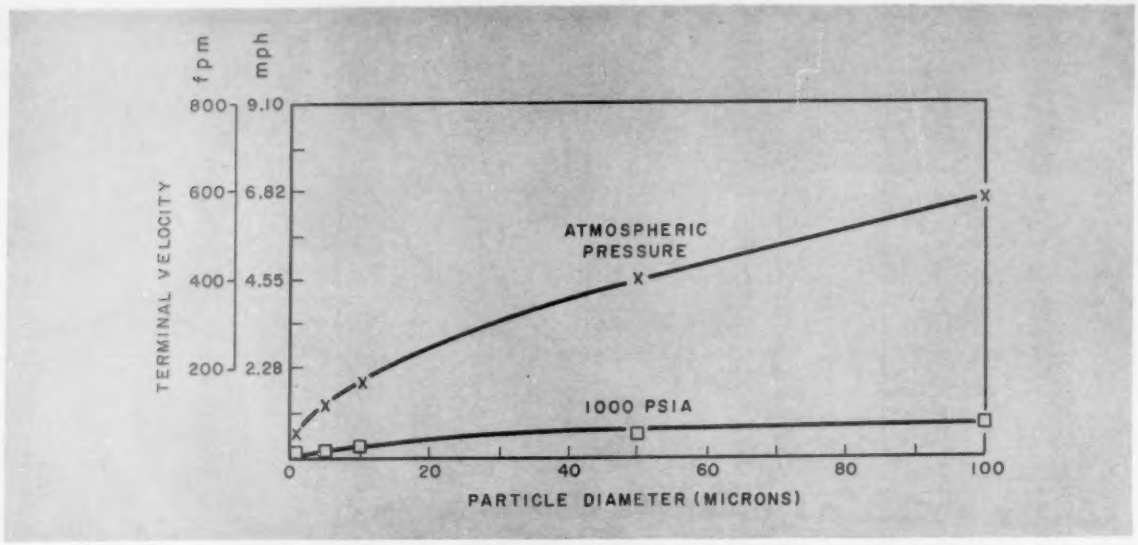


Fig. 6. Terminal velocity of various size particles in turbulent methane.

temperature gradients. Each of the phenomena can produce a velocity component normal to the pipewall. Some of the particles which are driven to the wall by these effects will remain there and cause a sampling error.

Brownian motion, caused by molecular bombardment, is an effect of very low order.

Average displacements for particles of various diameter in air and in methane are shown in Table 1. The displacements are all very small compared with the dimensions of the sampling probe, so that losses by this mechanism will be negligible.

Table 1. Particle Displacement Due to Brownian Motion.

Particle Diameter (microns)	in One Second (microns)	
	In Air at 70 F, 1 atm	In Methane 70 F, 1 atm
0.1	29.4	38.0
0.25	14.2	18.0
0.5	8.92	12.0
1.0	5.91	8.0
2.5	3.58	4.6
5.0	2.49	3.2
10.0	1.75	2.3

The effects of turbulence on diffusion to the wall are difficult to evaluate quantitatively. In turbulent flow the particles are moving with an average velocity in the direction of probe axis, but have varying velocity components in the direction of the wall. The particles near the wall may receive enough momentum to carry them through the stagnant gas layer at the probe wall and adhere to the probe. Turbulence can also produce the opposite effect, and remove particles from the wall and return them to the main gas stream. If the particles are not tightly adhering to the wall, these opposing effects will tend to cancel, with the net result that a sampling error due to turbulence can be expected to be small.

Motion toward the wall caused by temperature gradients within the probe is an effect of very small magnitude. It seems doubtful that this phenomena will result in any appreciable errors in a normal sampling probe.

A major cause of sampling error by motion to the wall may arise from electrostatic forces. Most aerosols carry a net electrical charge. This charge provides a force on the particles in the presence of an electric field that will drive them toward the walls, and cause them to adhere very tightly.

Experiments on sampling have indicated that this last phenomenon may cause a sizable sampling error.[8] The effect can be eliminated by inserting a radioactive material near the probe nozzle. This will neutralize the electric charge on the particles and prevent any motion due to electrostatic attraction.

Vertical Settling

The particles in a gas stream flowing in either a horizontal or vertical direction are subject to the earth's gravity. This will accelerate the particles in a downward direction. In a vertical section, the particles whose downward velocity is greater than the bulk upward velocity of the gas will fall through the rising gas stream and be lost. Therefore, the particles that will not be able to negotiate a vertical section in a probe are those that would settle through the gas with a velocity that is greater than the linear velocity of the gas. The settling velocity, or

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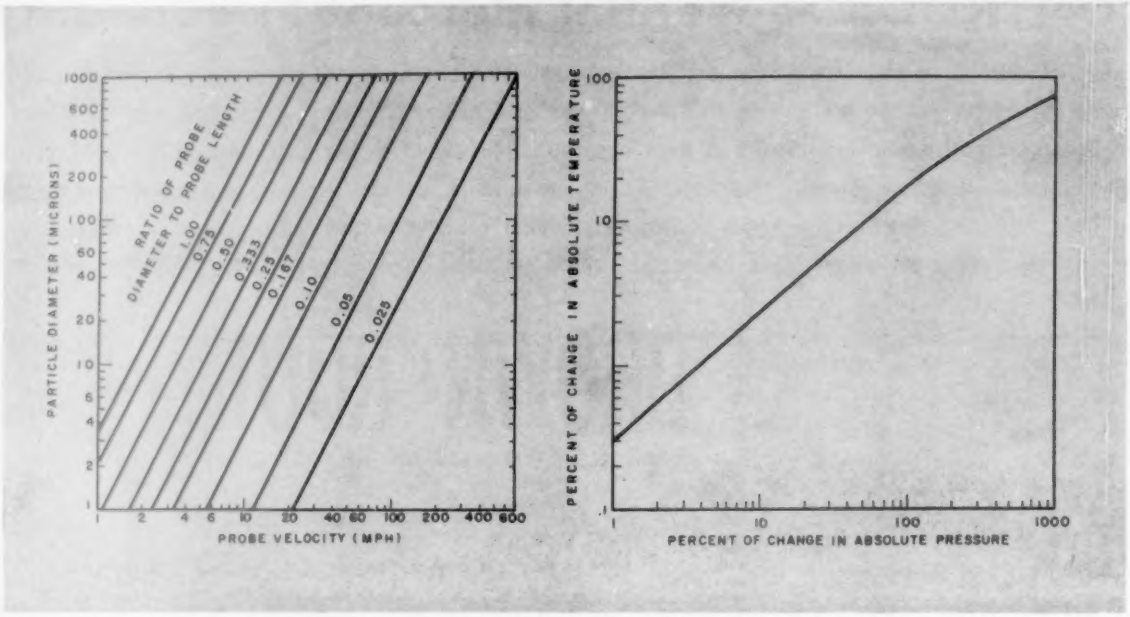

Fig. 7. Calculated particle diameter for 25% settling loss in horizontal probe.

Fig. 8. Change in absolute temperature with a change in pressure for methane with adiabatic expansion.

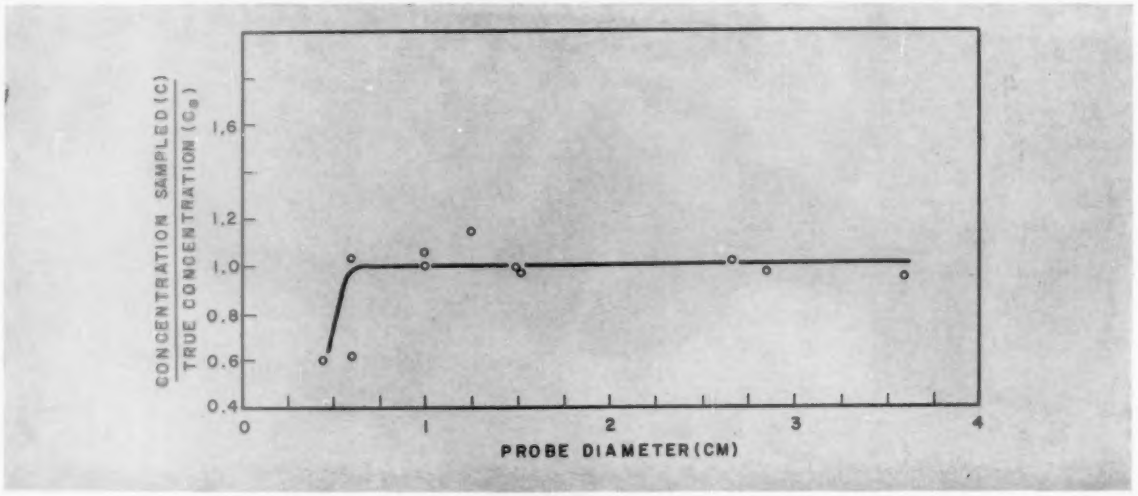

Fig. 9. Effect of probe diameter on sample concentration, based on data of H. H. Watson.

terminal velocity (V_T), of a particle in a turbulent gas is given by the expression:

$$V_t^2 = \frac{4gD_p}{3C} \frac{\rho - \rho_o}{\rho_o} \quad . \quad . \quad . \quad . \quad (3)$$

where g is the acceleration of gravity. The constant C is a function of the gas viscosity. For methane, C = 0.44. A graph of terminal velocities for particles of density, 2, is given in Fig. 6. Whenever this velocity is greater than that of the gas stream, the particles will not be carried up the sampling probe.

At 1000 psia, the terminal velocity of all particles with diameters less than 100 microns are less than 100 fpm (1.1 mph). This velocity is less than the probe velocities generally encountered in practice, so that errors due to vertical settling are practically nil. Even at atmospheric pressure the terminal velocity of 100μ particles is less than 600 fpm (6.8 mph). Since such small velocities are seldom encountered, errors due to this are rare.

Horizontal Settling

A fraction of the particles suspended in a turbulent flowing gas stream is constantly being lost by settling to the bottom of the pipe. At the same time, due to the turbulence in the pipe, a portion of the material that has collected on

the pipe walls is constantly being re-entrained in the gas. The net effect is an apparent constant concentration of particles in the gas when the flow conditions are uniform with respect to time. When a portion of the flowing gas enters a sampling probe, the turbulence in the probe decreases, due to the smaller diameter of the probe.

As a matter of fact, with a ⅜-in. probe, if the flow is less than approximately 15 mph the flow will be laminar and there will be no turbulence. Because of the smaller diameter of the probe, the time for a particle to settle to the bottom of the probe is less than in the pipe. Also, because of the decreased turbulence within the probe, fewer, if any, particles will be re-entrained, having settled. The net effect is a loss of particles due to settling in the horizontal runs in a probe.

If the assumption that all particles reaching the wall are trapped and not re-entrained, the sampling loss is given by:

$$E = \exp\left[-\frac{2L}{VD}\left(\frac{4g\rho}{3C\rho_o} D_p\right)^{1/2}\right] . \quad . \quad (4)$$

where:

E = fractional loss in particles
V = sampling velocity
D = probe diameter
g = acceleration of gravity
ρ = density of particle
ρ_o = density of gas
C = constant (0.44 for methane)
L = horizontal length of the probe

Using this expression, curves corresponding to 25% particle loss were calculated and are illustrated in Fig. 7. Losses will be greater than 25% for particles larger than the indicated size and smaller for smaller particles.

The losses, in general, will be lower than predicted due to re-entrainment. For minimum loss, the probe should be as short as possible and as large in diameter as is practical. Under most conditions, velocities will be in the range of 10 to 50 mph. Consequently, in order to collect particles up to 10 microns with minimum loss the ratio of probe diameter to probe length should be greater than approximately 0.17. For a ½-in. probe this means that the horizontal run should be less than about 3 in.

Changing Temperature

Heating or cooling a sample line that contains vaporizable or condensable components would be expected to change the concentration of these materials as suspended particles. On the other hand, when the suspended material is a solid and there are no condensable or vaporizable components in the gas stream, heating or cooling does not effect the number or size of the particles.[6]

When a gas is expanded or compressed adiabatically, the temperature of the gas is related to the pressure of the gas by the expression:

$$\frac{T_B}{T_A} = \left[\frac{P_B}{P_A}\right]^{\frac{k-1}{k}} . \quad . \quad . \quad . \quad . \quad 5$$

where A and B refer to the initial and final states, T is the absolute temperature, P is the pressure, and k is the ratio of heat capacities $\frac{C_P}{C_V}$. For methane, k is equal to 1.3.

Fig. 8 gives the percentage change in the absolute temperature for various percentage changes in the pressure. It may be seen that small changes in pressure can result in very appreciable changes in temperature; for example, if methane at 25 C were subjected to an expansion that changed the pressure by 10%, the absolute temperature would change by 2.3%, or 6.9 C.

The change in the concentration of liquid suspensoids when compressing or expanding the gas in the sampling line can be determined. These erors can be very large for liquid particles. For example, a temperature change of 5 C in a gas saturated with pentane at 25 C could condense 15 tons of pentane per MMcf. Errors of this nature can be eliminated only by proper design of the probe (uniform cross section throughout), and by rigorously maintaining the gas at constant temperature.

Sampling Nozzle Diameter

Earlier, the necessity for isokinetic sampling in order to obtain a representative sample was discussed. Even at isokinetic conditions, errors may be introduced if the probe diameter is smaller than a critical size.

The effect of probe diameter on particle concentration is shown graphically in Fig. 9. Here it is seen that below about 0.6-in. the sample concentration drops very rapidly.

Other investigators have found that probes of diameters 0.25 to 0.40-in. could be used without introducing serious errors.[3,4,7] The explanation for the errors is based on the effect of the bluffness of the probe, i.e., the ratio of probe wall area to probe aperture area. Use of a feathered or streamlined nozzle will tend to eliminate this type of error.

Part 3-B will discuss "Recommendations for Sampling."

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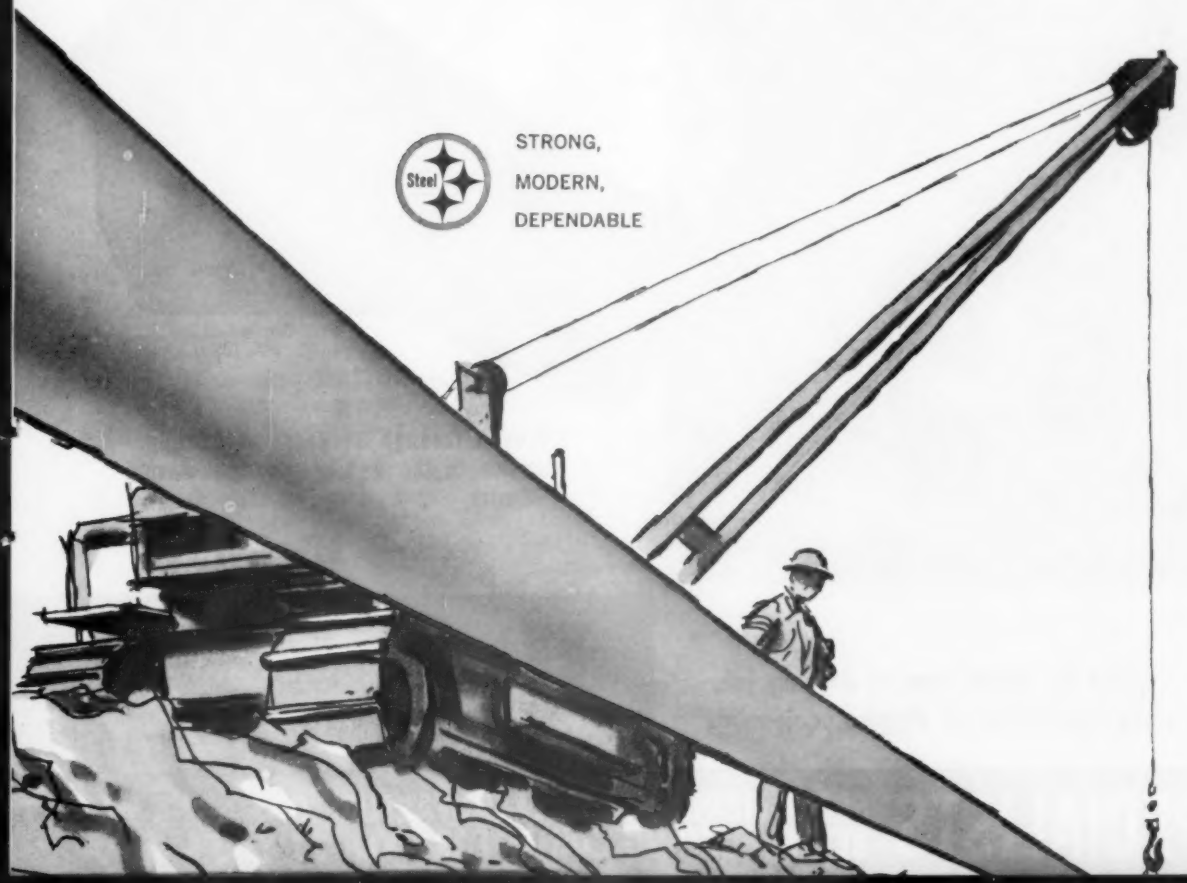

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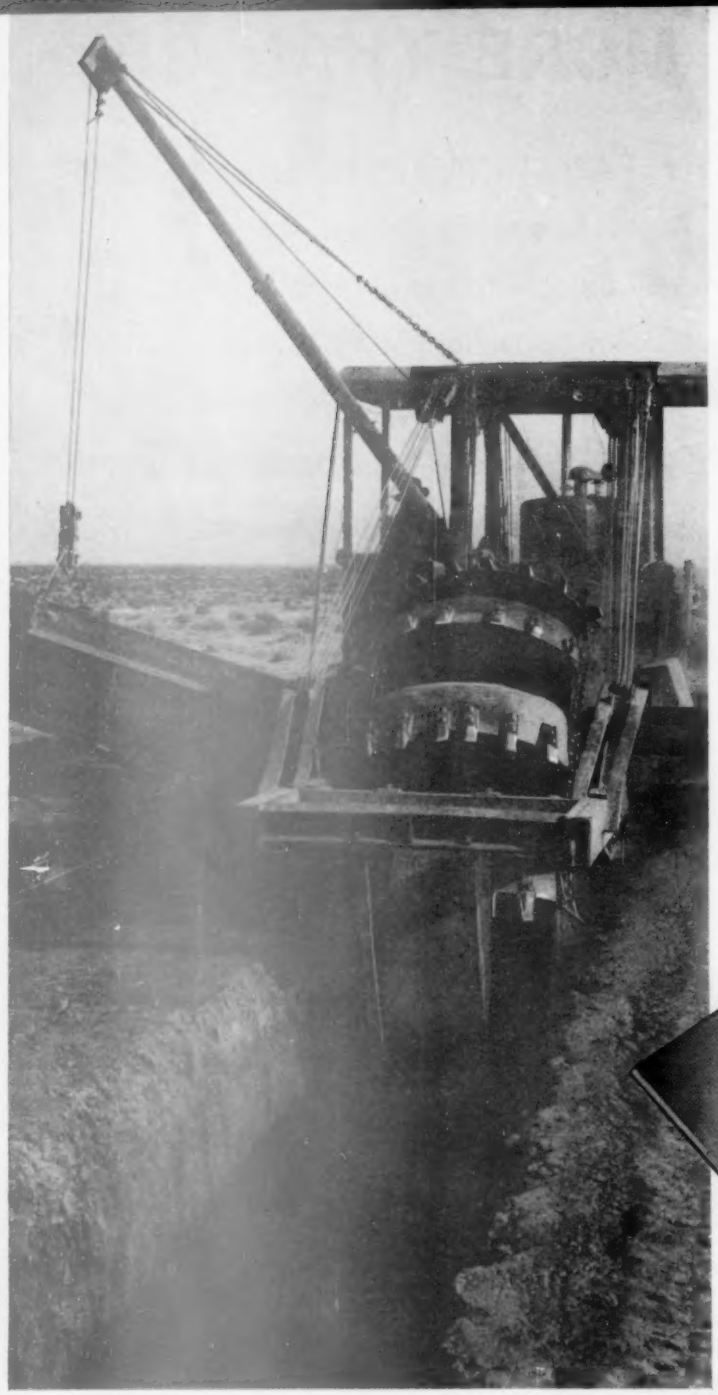

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Coming Construction

Gulf-Baltimore Line Studied

A group of major oil companies is considering a petroleum products pipeline from Gulf of Mexico refining centers to Norfolk, Washington and Baltimore.

The 22-in. line, with a capacity of 300,000 bpd, would decrease dependence on tankers.

Companies which are said to have an interest in the project are Gulf Oil Corp., Texaco, Inc., Sinclair Oil Corp., American Oil Co., an affiliate of Standard Oil Co. of Indiana, Pure Oil Co., Empire Pipeline, Phillips Petroleum and Continental Oil.

Sinclair would operate the new Suwannee Pipeline Co., but there would be varying degrees of ownership among the companies involved. It is understood that Wendell Ramsey of Gulf's transportation department in Pittsburgh would be named president of the new firm.

The line would be linked with refineries in the Houston, Beaumont and Port Arthur areas of Texas and also hook up with two other existing pipelines.

Based on the 120,000-bbl-capacity of T-2 tankers, the pipeline would replace 25 such tankers, or 10 larger 300,000-bbl-capacity tankers.

Pennsy Eyes Avi-Fuel Line

A pipeline network to serve major airports in the Washington and Baltimore areas is under consideration.

The Potomac Public Service Co., controlled by the Pennsylvania Railroad, announced that engineering phases are being worked out by Sverdrup & Parcel and Pipe Line Technologists, Inc.

The railroad revealed that the proposed pipeline system would use Pennsy's rights-of-way for portions of the approximate 80 mile distance from an originating terminal in the Curtis Bay area, south of Baltimore, to the Dulles International Airport, now under construction at Chantilly, Va.

The company also contemplates reaching Washington National Airport, Andrews Air Force Base, and Friendship International which serves both Baltimore and Washington.

The new facility would be available to all shippers desiring to use it to transport fuel supplies to the airports. Automotive gasolines and fuel oils also would be delivered at various points along the network.

Gas Liquids Systems Okayed

The Alberta Oil and Gas Conservation Board has recommended to the provincial government the approval of three proposed pipeline systems to carry wet gas liquids, mainly condensate, out of Alberta fields which gas export to California will activate next winter:

Britamoil Pipeline, Ltd. (subsidiary of The British American Oil Co., Ltd.) — a 60-mile, 8-in. from Rimbey gas field to Edmonton.

Royalite Oil Co., Ltd. — a 40-mile, 4-in. from Wildcat Hills and Jumping Pound gas fields to the existing Valley pipeline near Turner Valley for shipment to Calgary refineries.

Hudson's Bay Oil and Gas Co., Ltd. — 50 miles of 4 and 8-in. from Waterton and Pincher Creek gas fields to near Carway to the Alberta-Montana border.

If and when the government confirms the recommendations, tenders will be called immediately so that work can be completed in the fall. All applicants stated they would be in a position to complete their projects concurrently with the Alberta-California big-inch gas transmission project.

Gas Gathering System Slated

Tex-Star Oil & Gas Corp. plans to construct a new gathering system in Live Oak County, Tex., to deliver gas to the Lo-Vaca Gas Gathering System which is now under construction by Coastal States Gas Producing Co.

Deliveries, under a 20-year contract with Coastal States, are scheduled to begin Sept. 1, 1961, at a minimum starting rate of 5000 Mcf daily, increasing to 9200 Mcf daily on April 1, 1962. The Lo-Vaca system will deliver to Alamo Gas Supply Company for the city of San Antonio starting April, 1962.

Tex-Star points out that prospects for expansion are most promising in view of extensive drilling activity taking place in the Live Oak County area. The system is being engineered specifically to accommodate substantial increases in throughput as the need arises. Uncompressed capacity will be 25,000 Mcf of gas per day.

When Tex-Star has recouped its cost in addition to certain other adjustments, according to the agreement, Coastal States will be entitled to one-half interest in the gathering facilities.

Pembina Gathering System

An application is expected soon for a large gas byproducts gathering system in the southeastern sector of Pembina oil field of Alberta.

Thirteen companies, headed by Canadian Delhi Oil, Ltd., are sponsoring the proposed gathering system which would consist of approximately 100 miles of 3 to 8-in. lines. It would feed into a gas processing and liquids recovery plant in the vicinity of Buck Lake and Minnehik. Plant capacity would be 41,000,000 cu ft per day of wet gas.

FPC Okays Lines, 4 Budgets

The Federal Power Commission has authorized pipeline construction by El Paso Natural Gas Co., Hope Natural Gas Co., and Colorado-Wyoming Gas Co., at a combined cost of $2,714,630, as well as "budget" construction proposed by Texas Gas Transmission Corp., Michigan Wisconsin Pipe Line Co., Kansas-Nebraska Natural Gas Co., Inc., and Coastal Transmission Corp.

El Paso will construct about 37 miles of 8-in., a meter station and appurtenant equipment at a cost of approximately $949,000 for sale to Southern Union Gas Co. The gas will be resold to Southwest Forest

Industries, Inc., in Navajo County, Ariz.

Hope, in two stages, will extend its Fink storage pool in West Virginia and replace present gathering facilities. The firm in 1961 will construct about 6 miles of small diameter pipeline to replace part of the old gathering system, connect 15 former oil wells to the new gathering line, and connect this new line to the remaining portion of the old system. This will cost about $320,000. In 1962 the firm will build about 12 miles of small diameter pipe to replace another part of the old system and connect 61 former oil wells at a cost of about $470,000.

Colorado-Wyoming will lay about 17 miles of 16-in. in Adams and Boulder counties, Colo., plus two meter stations in Jefferson and Adams counties, at an estimated $975,630.

Texas Gas will construct facilities not to exceed a total of $3,000,000 with single projects limited to $500,000.

Michigan Wisconsin will construct facilities not to exceed a $3,000,000 total, with single projects limited to $500,000.

Kansas-Nebraska's "budget" calls for facilities not in excess of $1,500,000, with the cost of single projects limited to $500,000.

Coastal is directed to construct $1,500,000 in facilities, with single projects limited to $300,000.

Alberta Gas To Go Into B.C.

Alberta Gas Trunk Line Co., Ltd., has applied for permission to lay its first pipeline across a provincial boundary.

The project involves between 40 and 50 miles of 12 and 16-in. from Worsley gas field in northwestern Alberta and Boundary Lake South gas field in northeastern British Columbia to the present gathering system of Westcoast Transmission Co., Ltd., near Fort St. John, B.C.

Gathering System Planned

Lone Star Gas Co. has announced plans to form a wholly-owned subsidiary, Lone Star Gathering Co., to build a $2,500,000 gathering system in south Texas.

The 63 miles of various size lines in DeWitt and Victoria counties will connect 32 gas wells.

Capacity will be 60,000,000 cu ft of gas per day.

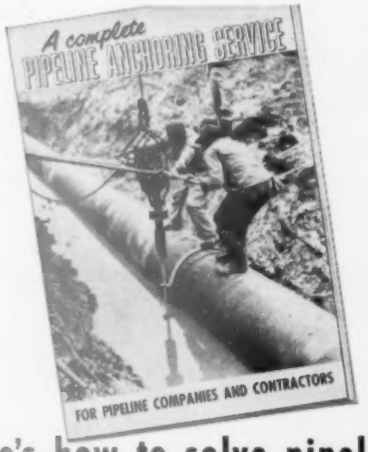
Internationally...

Petroleos Mexicanos, it is reported, plans to extend its Salamanca-Ciudad Pemex-Mexico City gas pipeline to San Luis Potosi and Guadalajara.

Alberta Gas Trunk Line Co., Ltd., is considering further plant expansion next year. Cost is expected to total $14,000,000.

SEC Report

Magna Pipe Line Ltd., the firm undertaking construction of an underwater natural gas transmission line from the British Columbia mainland to Vancouver Island and a land line on the island, seeks registration of 114,750 shares of common stock in exchange for common shares of Natural Gas Transmission Co., at the rate of four shares of Magna for 10 shares of NGT, and 750,000 common shares of which 525,000 will be offered for sale in the U.S. and the balance in Canada. Total 1961 construction costs for both companies (NGT plans a natural gas line from Bremerton, Wash., to Port Angeles, Olympic



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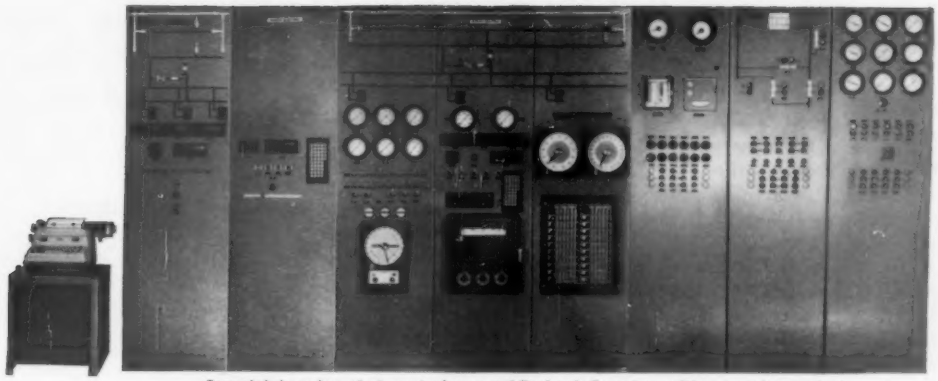

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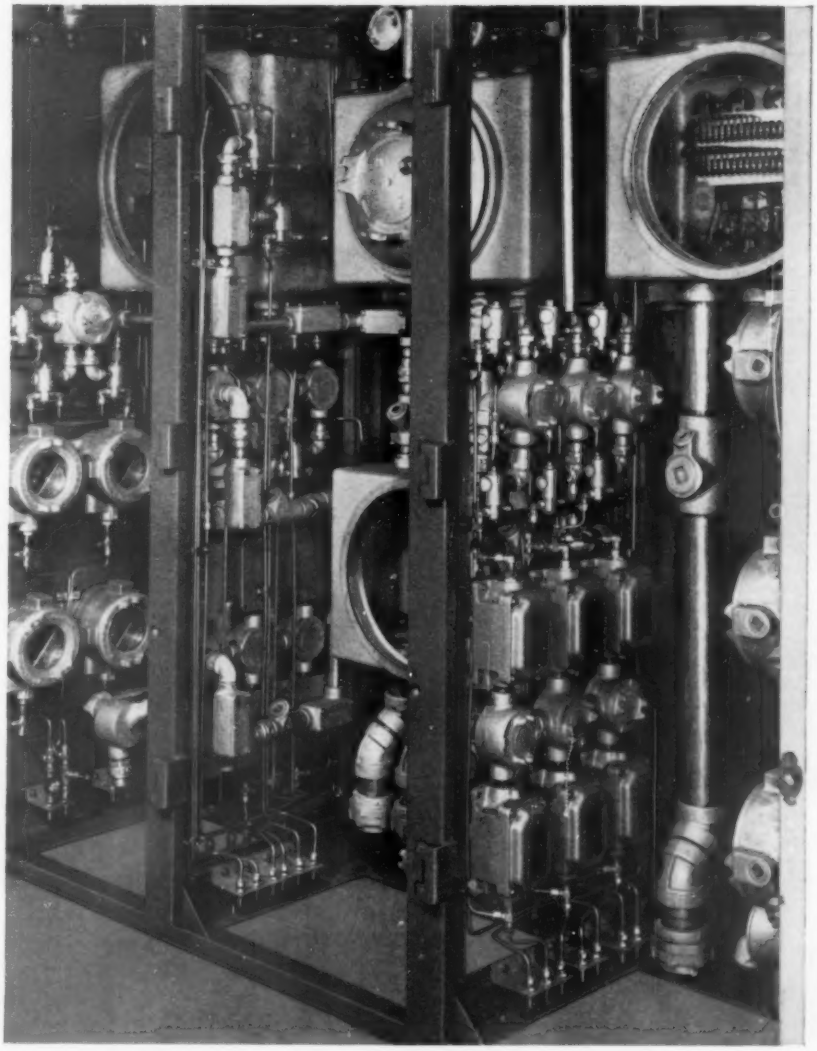

Represented by: Lynn McGuffy Company, Inc., 304 Sklar Bldg., Shreveport, Louisiana

ELECTRONETICS DIVISION **NORTH ELECTRIC COMPANY**
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Peninsula, Wash., is estimated at $4,300,000. A total of $30,000,000 will be spent through 1967.

Texas Eastern Transmission Corp. seeks registration of $30,000,000 of debentures due July 1, 1981, and 200,000 shares of $100 par preferred stock, subordinate convertible series. Net proceeds will be used to retire currently outstanding notes and to finance 1961 construction which is estimated at $89,000,000. Financing has already been provided in part by sale of $30,000,000 of first mortgage pipeline bonds and $15,000,000 par value of preferred stock in January, 1961.

SEC has issued an order authorizing Michigan Wisconsin Pipe Line Co. to issue and sell to banks during 1961 promissory notes not to exceed $20,000,000, proceeds of which will be applied to the company's 1961 construction program.

The Houston Corp. seeks registration of 583,334 shares of common stock to be offered for subscription by holders of the company's Class A and common stock. Net proceeds from the sale, plus proceeds of the sale of certain other securities, will be applied to the company's expansion program of $31,100,000.

FPC Filings

Arkansas Louisiana Gas Co., Shreveport, La., CP 61-311, filed June 5, 1961. *Construction:* connections with Texas Eastern Transmission Corp. where pipelines intersect in Harrison County, Tex., and Grant County, Ark., to permit applicant to sell to TET for a one-year period.

Cost: $187,965 total, of which $11,890 is for Texas connection and $176,075 is for Arkansas connection. Former includes: $10,035, meter and regulator; $1355, tap; and $500, site. The latter: $8665, meter facilities; $1060, tap; $1000, site; $9050, communications; and $156,300, compressor facilities.

Colorado Interstate Gas Co., Colorado Springs, Colo., CP-61-336, filed June 22, 1961. *Construction:* meter station on Kit Carson-to-Denver main line and transfer of city gate meter station at Hugo and existing 6-mile, 4-in. lateral between Hugo and main line to Kansas-Colorado Utilities, Inc.

Cost: $13,530 total for meter station, which includes: land and rights, $300; measuring and regulating station structures, $3300; measuring and regulating equipment, $8700; overheads and interest, $615; contingencies, $615. Kansas-Colorado will pay $26,200 for existing facilities to be transferred.

Manufacturers Light and Heat Co., Pittsburgh, Pa., CP 61-342, filed June 27, 1961. *Construction:* 130-hp Clark CFA-2, skid-mounted, semi-automatic compressor station at Irwin storage field, North Huntgindon Township, Westmoreland County, Pa.

Cost: $70,000 total which includes: land, $2000; compressor building, $2900; compressor unit, $28,000; compressor fuel measuring and regulating equipment, $700; plant pipe, valves, fittings, $6000; gas scrubber, $2100; miscellaneous, $3000; labor, inspection, corrosion, engineering, supervision, $11,600; construction cost by contract, $3000; other costs, $4030; construction overheads, $6670.

Mississippi River Fuel Corp. and Mississippi River Transmission Corp., St. Louis, Mo., CP 61-341, filed June 27, 1961. *Construction:* interconnection near Granite City, Madison County, Ill.

Cost: $38,500 total, of which Mississippi Fuel pays $24,950 and

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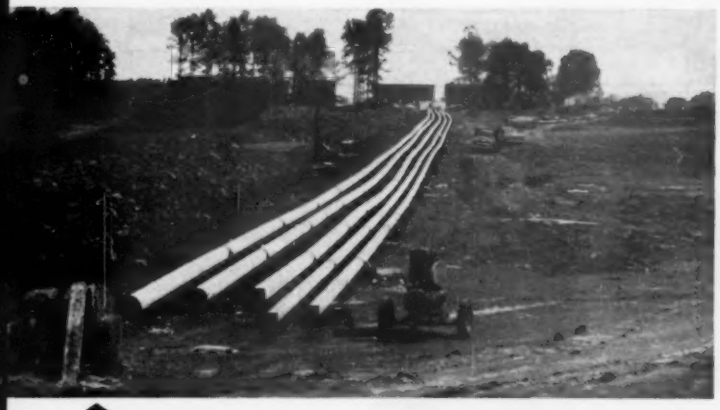

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Mississippi Transmission pays $13,550. Total includes: $7200 for connection and line pipe; $7400 for meter tubes, valves, regulators, pipe and instruments; $8000, land in fee; $4000, roadway; $1750, contingencies; $1050 for engineering, supervision, legal and overhead; $700, interest.

United Gas Pipe Line Co., Shreveport, La., CP 61-331, filed June 19, 1961. *Construction:* 10.2-mile, 30-in. loop northwesterly from the intersection of the 20-in. Turtle Bayou field lateral and the 24-in. from the Lirette area in Terrebonne Parish, Louisiana, to a point in Assumption Parish.

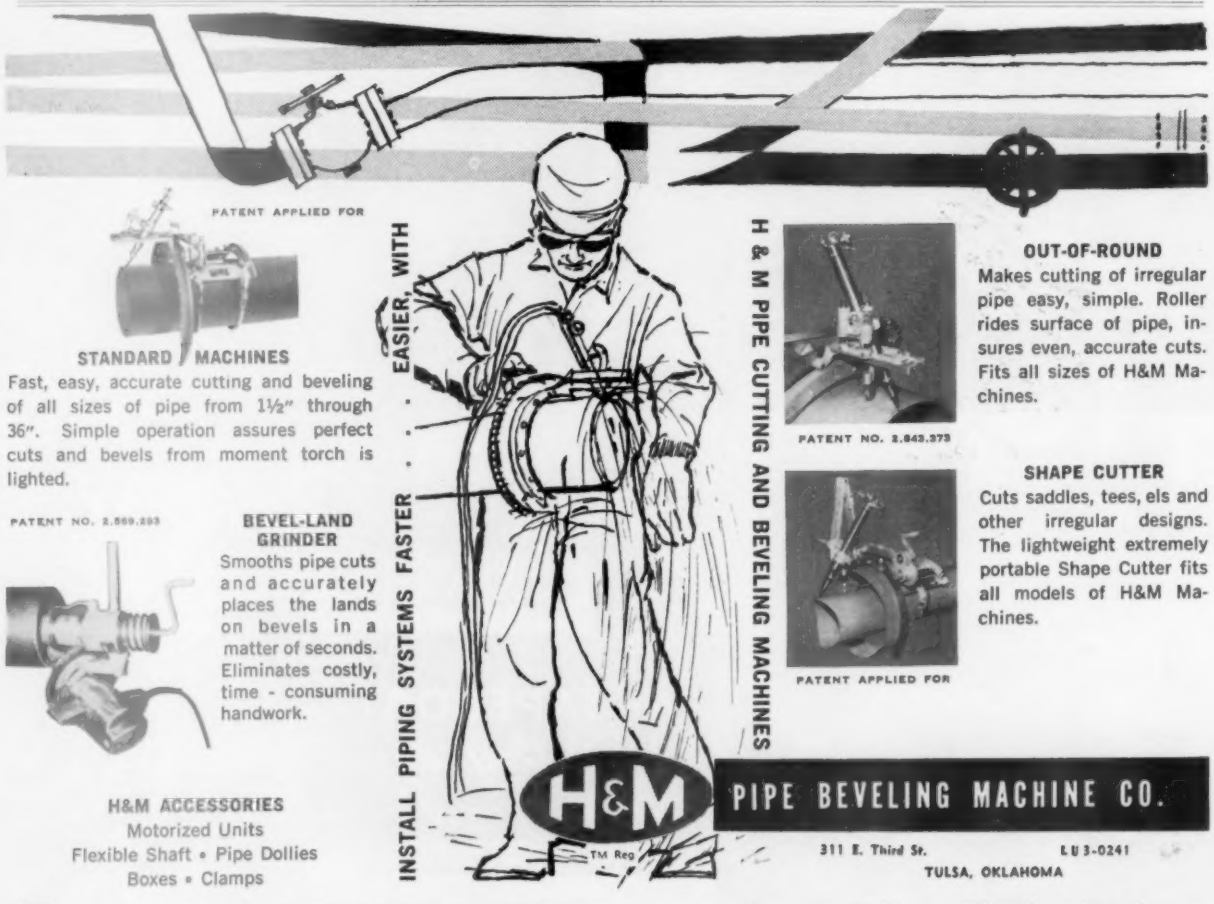
Cost: $1,959,917 which includes: right-of-way, $38,250; damages, $38,250; surveys, $10,200; materials, $1,046,089; installation, $618,642; overhead, $87,572; interest, $27,585; and contingencies, $93,329.

Natural Gas Pipeline Co. of America, Chicago, Ill., and Mississippi River Transmission Corp., St. Louis, Mo., CP 61-339, filed June 26, 1961. *Construction:* interconnection at a point in Clinton County, Ill., near Carlyle — necessary taps to be separately owned, metering facilities to be jointly owned. NGPL will interconnect its proposed 30-in. line (see CP 61-30 and CP 61-185) if authorization received in time and, if not, will interconnect existing 30-in. in same location.

Cost: $22,550 for meter facilities which includes: $10,000 for meter tubes, valves, regulators, pipe and instruments; $4000, installation; $2500, land; $3000, roadway; $2050, contingencies; $1000, engineering, supervision, overhead. Separately-owned side taps: NGPL — $2800 if made on existing 30-in., $4000 if made on proposed 30-in.; Mississippi River Transmission—$2500 on existing 18-in.

Transcontinental Gas Pipe Line Corp., Houston, Tex., CP 61-328, filed June 19, 1961. *Construction:* 4200-hp compressor station, 115.5 miles of purchase laterals and four purchase meter stations and equipment to receive gas from Gulf Oil Co. and Socony Mobil Oil Co. in Vermilion, South Marsh Island, Ship Shoal areas, offshore Louisiana.

Cost: $16,700,000. (Note: this is a duplicate of CP61-294, filed May 18, 1961, which was rejected by FPC letter of June 9 for lack of inclusion of flow and other data. This new application includes the requested data.)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Pipeline Contractors

Alberta Consolidated Pipe Line Builders. *Alberta Gas Trunk Line Co., Ltd.* — 113 miles of 36-in. from Priddis, Alta., to a point near Rocky Mountain House, and 64 miles of 16-in. from the main line near Waterton Park gas field to the Montana border near Carway. Alberta Consolidated is a joint venture of Mannix Co., Ltd., and Piggott Construction, Ltd., both of Calgary; Banister Construction Co., Ltd., Edmonton; and Marine Pipeline and Dredging, Ltd., Vancouver.

Contracting & Material Co., 1235 Dodge Ave., Evanston, Ill. *West Shore Pipe Line Co.* — 32 miles of products main line in Illinois, including a lateral extension to Blue Island, with 4 miles of receiving lines from refineries in the Lockport and Lemont areas to the Romeo station site; and, also in Illinois, 32 miles of main line and 1 mile of delivery line to facilities in the vicinity of Des Plaines terminal.

Contracting and Trading Co. (Kuwait), Box 1036, Beirut, Lebanon. *Arabian Oil Co.* — coating 45 miles of 12, 14, 16, 26 and 30-in. in the neutral zone.

Davis Construction Co., 709 N. Broadway, Cleveland, Okla. *Northern Natural Gas Co.* — 116 miles of 2 through 8-in. in Minnesota.

O. R. Burden Construction Corp., Box 5216, Tulsa, Okla. *Alamo Gas Supply Co.*—291 miles of 14 through 24-in. in southwest Texas to supply gas to San Antonio.

Dixie Pipe Line Co.—Griffin, Ga., to McBee, S.C., portion of 1100-mile, 6, 8, 10 and 12-in. LPG line.

Canadian-Parkhill Pipe Stringing, Ltd., 164 Eglinton Ave., E., Toronto, Ont., Canada. *Alberta Gas Trunk Line Co., Ltd.* — under subcontract from Dutton-Williams Bros., 20 miles of 22-in. and 62 miles of 30-in. from Windfall to Lovett River; under subcontract with Majestic Contractors, Ltd., 63 miles of 30-in. and 38 miles of 22-in. from Lovett River to Rocky Mt. House, and 113 miles of 36-in. from west of Calgary to the British Columbia border; and under subcontract from Piggott Construction, Ltd., 64 miles of 16-in. from the southend lateral to the Montana border. Field office: Calgary. Curtis Williams is general superintendent, Wes Strangh is office manager.

Canadian Bechtel, Ltd., 25 King St., W., Toronto 1, Ont., Canada. *Western Pacific Products and Crude Oil Pipelines, Ltd.* — 145 miles of 12-in. in British Columbia from Taylor to Pine Pass.

Banister Construction Co., Ltd., 625 Northern Hardware Bldg., Edmonton, Alta., Canada. *Saratoga Processing, Ltd.*—45 miles of 16-in. and 15 miles of 4 to 6-in. natural gas pipeline from Savanna Creek to Coleman, Alta., where field office is located. George Caron is general superintendent.

Petrogas Processing, Ltd. — 208-mile, 2 through 8-in. gathering system, with Max Sanderson as general superintendent.

Panama-Williams Corp., 1418 Melrose Bldg., Houston, Tex. *West Shore Pipe Line Co.* — 76 miles of 16-in. products line in Milwaukee, Washington, Sheboygan, Calumet and Manitowoc counties, Wis. This extends from Granville station site in Milwaukee County to the Brown County line.

Dutton-Williams Bros., Ltd., North Canadian Oil Bldg., Calgary, Alta., Canada. *Alberta Gas Trunk Line Co., Ltd.* — 62 miles of 30-in. from West Cynthia to West Whitecourt, Alta., and 20-mile, 22-in. lateral from this main line to the Whitecourt field. Harland Evens is project manager.

Western Pacific Products and Crude Oil Pipelines, Ltd.—360 miles of 12-in. in British Columbia from Prince George to Kamloops, under supervision of Harland Evens and E. Maddoms.

Hall Construction Co., 1105 N. Carlton, Liberal, Kan. *Panhandle Eastern Pipe Line Co.* — a 330-mile, 4 through 12-in. gathering system in western Kansas. Supervising are Mike Bell and M. E. Banning.

Harbert Construction Corp., Drawer 75, Birmingham, Ala. *Northern Natural Gas Co.* — 138 miles of 2 through 8-in. lateral lines in Minnesota. Field office: Pine Island. Superintendent: Jay Cundiff.

R. H. Fulton & Co., Box 1526, Lubbock, Tex. *Continental Pipe Line Co.* — 550 miles of 2, 3, 4, 6 and 8-in. in Montana and Wyoming.

Northern Natural Gas Co. — 87 miles of 24 and 30-in. loops from near Beaver, Okla., to near Albert Lea, Minn.; 60 miles of 26-in. east of Ogden, Iowa; and 64 miles of 26-in. east of Waterloo, Iowa.

Sinclair Pipe Line Co.—170 miles of 8-in. from LaVerne to near Newalla, Okla.

Anadarko Production Co. — 83 miles of 10 and 12-in. in Kingman, Sedgwick and Butler counties, Kan.

Grayco Constructors, Inc., Box 4147, Austin, Tex. *Trunkline Gas Co.* — 22 miles of 18 and 20-in. from six miles south of Delcambre to Cow Island, all in Vermilion Parish, La. Headquarters: Abbeville. Superintendent: Emmett E. Wilkerson.

Brodie Construction Co., Box 2646, Amarillo, Texas. *Northern Natural Gas Co.* — 176 miles of 2 through 8-in. in Iowa.

C. S. LeNoir Construction Co., Box 798, Austin, Tex. *Transcontinental Gas Pipe Line Corp.* — 83 miles of 36-in. in four loops: 21 miles in Walthall, Marion and Jefferson Davis counties, Miss; 12 miles in Choctaw County, Ala.; 32 miles in Perry and Dallas counties, Ala.; 18 miles in Autauga and Chilton counties, Ala. Headquarters: Columbia, Miss. Superintendent: W. B. Williams.

Majestic Contractors, Inc., sub-

sidiary of Majestic Contractors, Ltd. *Montana Power Co.* — 56 miles of 16-in. from Cut Bank, Mont., headquarters, to the Canadian border near Carway, Alta.

Majestic Contractors, Ltd., 49 Jackes Ave., Toronto 7, Ont., Canada. *Canadian-Montana Pipe Line Co.* — 4 miles of 16-in. from near Carway, Alta., to the Montana border. Cut Bank, Mont., is project office.

Mannix Co., Ltd., 737 — 8 Ave., S.W., Calgary, Alta., Canada. *Alberta Gas Trunk Line Co., Ltd.* — compressor station at Princess, Alta., under the supervision of J. Hobbs.

Midwestern Contractors, Inc., 130 W. Liberty Dr., Wheaton, Ill. *West Shore Pipe Line Co.* — in Lake County, Ind., 10 miles of products line including 2 miles of main line and 8 miles of receiving line from shippers' tank farms in the area to firm's Hammond station.

J. P. Neill and Co., Meadows Bldg., Dallas, Tex. *Pacific Gas Transmission Co.* — 468 miles of 36-in. from California-Oregon boundary to Rosalia, Wash., as joint venture with Western Pipelines, Inc. Colfax, Wash., is field office now for a 152-mile, 36-in. segment from Stanfield, Ore., to Rosalia, Wash. Jack Hays is superintendent.

Houston Contracting Co., 2807 Buffalo Speedway, Houston 6, Tex. *West Shore Pipe Line Co.*—61 miles of 16-in. products line in Cook and Lake counties, Ill., and Kenosha, Racine and Milwaukee counties, Wis. A. J. Slovack will supervise, with initial headquarters at Union Grove, Wis.

Texas Eastern Transmission Corp. — 161 miles of 20-in. from West Monroe, La., to Kosciusko, Miss.

Dixie Pipe Line Co. — 226 miles of 10-in. LPG from Mont Belvieu, Tex., to Baton Rouge, La.

Transcontinental Gas Pipe Line Corp. — four loops consisting of 65 miles of 30 and 36-in. from Fulshear, Tex., to New Roads, La., under the supervision of M. L. Thompson.

Pease Bros. Co., 120 E. Main St., Vernal, Utah. *Mountain Fuel Supply Co.* and *Utah Natural Gas Co.*—103 miles of 20-in. from the Uintah Basin to Clear Creek, Carbon County, Utah.

Pentzien, Inc., 1504 Dodge St., Omaha, Neb. *West Shore Pipe Line Co.* — single 10-in. crossing of the Fox River near Green Bay, Wis., under subcontract from Somerville Construction Co. Superintendent: T. D. Stout.

H. C. Price Co., Price Tower, Bartlesville, Okla. *Pacific Gas & Electric Co.* — 296 miles of 36-in. to the Oregon border from the San Francisco Bay area. Superintendent; R. L. Ezell. Office manager: Bob Walker.

Pacific Gas Transmission Co. — 146 miles of 36-in. from Rosalia, Wash., to the Idaho-British Columbia border. Superintendent: G. A. Reutzel. Office manager: E. Dickson at Veradale, Wash. *Texas Eastern Transmission Corp.* — 26 miles of 30 through 36-in. in New Jersey from near Lambertville to New Brunswick, with Elwood Roth supervising. Nick Beffer is office manager at Flemington.

Price-Poole of Canada, Ltd., Box 969, Cranbrook, B. C., Canada. *Alberta Natural Gas Co.* — 107 miles of 36-in. from Crowsnest Pass to the Idaho boundary at Kingsgate-Eastport. Joint venture of H. C. Price Co. of Canada, Ltd., Calgary, and Poole Construction Co., Ltd., Edmonton. C. E. Shivel is superintendent, and Wayne McKnight is office manager at Cranbrook, B. C.

Panama, Inc., 1801 Tennessee Bldg., Houston 2, Tex. *Northern Natural Gas Co.* — 82-mile, 20-in. from Menominee, Ill., to Janesville, Wis., under the supervision of A. J. McIntyre.

R. E. Reutzel Co., Inc., Box 727, Fremont, Neb. *Northern Natural Gas Co.* — 116 miles of 2, 3, 4, 6 and 8-in. in South Dakota. Spreadman: James Adcock. Office manager: R. E. Whitworth.

S.A.I.P.E.M., Casella Postale 4159, Milan, Italy. *Oil India Private, Ltd.* — 720 miles of 14, 16 and 18-in. from Nahorkatiya to Barauni.

Baghdad, Iraq, Ministry of Industry — 56 miles of 10, 14 and 18-in. from Rumaila to Basrah.

SNAM (Oleodotti Internazionali) — 116 miles of 24 and 26-in. from Genoa to Ponte Tresa; 73 miles of 16 and 18-in. from Ferrera to S. Bernardo; 76 miles of 22 through 24-in. from Ponte Tresa to Thusis; 77 miles of 22-in. from Thusis to Ollenweil; and 37 miles of 12-in. from S. Bernardo to Aigle. Also for SNAM, 59 miles of 18 through 20-in. from Cremona to Brugherio.

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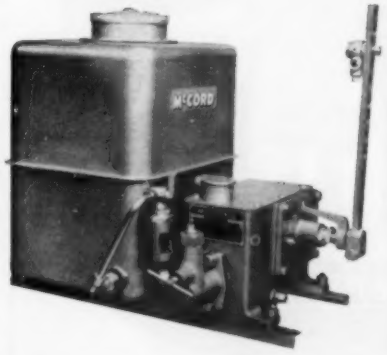

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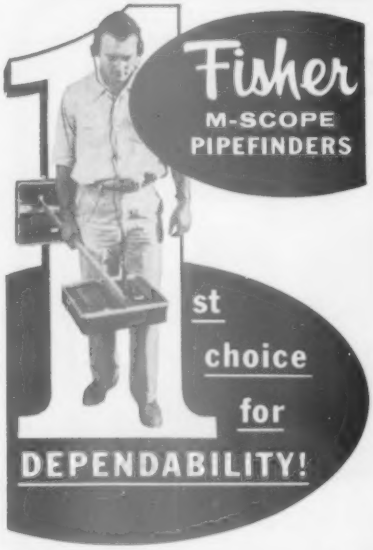

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Y.P.F. (Buenos Aires, Argentina) — 106 miles of 6, 8 and 10-in. in the Comodoro oil field.

Shamrock Construction Co., Box 1177, Lansing, Mich. *Northern Natural Gas Co.*—130 miles of 2 through 8-in. laterals in Iowa.

Shamrock Constructors, Inc., Box 505, Dodge City, Kan. *Mustang Fuel Corp.* — 77 miles of 12-in. gathering lines in Canadian, Dewey, and Blaine counties, Okla. Headquarters: El Reno.

Sharman, Allen, Gay & Taylor, Inc., Box 13152, Houston, Tex. *Dixie Pipe Line Co.* — from the Mississippi River to Demopolis, Ala. — a portion of the 1100-mile, 6, 8, 10 and 12-in. LPG line.

Sheehan Pipe Line Construction Co., 514 National Bank of Tulsa Bldg., Tulsa, Okla. *Transwestern Pipeline Co.* — has underway an additional 100 miles on the 4, 6, 8, 10, and 12-in. gathering system in Oklahoma, Texas, and New Mexico.

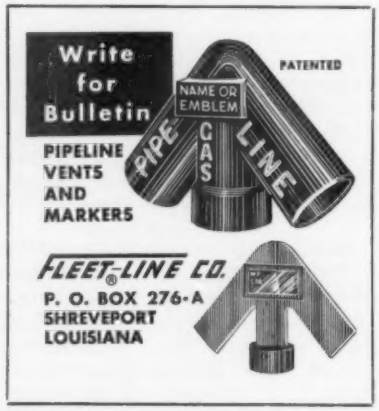
SunOlin Chemical Co. — 50 miles of 6-in. and 30 miles of 4-in. in New Jersey from Paulsboro, where headquarters is located, to Deepwater. C. M. Brown is superintendent.

Somerville Construction Co., 6648 Fulton Rd., East Ada, Mich. *West Shore Pipe Line Co.* — 23 miles of 10-in. and 43 miles of 16-in. products line in the vicinity of Milwaukee, Wis. Field offices: Green Bay and Milwaukee. Superintendent: Harold Cook.

Stanley-Bledsoe Corp., 612 Daniel Bldg., Tulsa 3, Okla. *Pacific Gas Transmission Co.* — double-jointing and yard-treating 466 miles of 36-in. in three schedules in Klamath, Jefferson, Umatilla and Gilliam counties, Ore., and Walla Walla and Whitman counties, Wash. Superintendent: W. D. Smith, Jr.

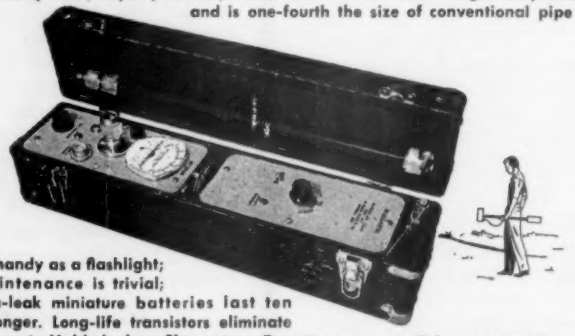
Dixie Pipe Line Co. — 30 miles of 8-in. and 96 miles of 6-in. from north of McBee, Chesterfield County, S.C., to south of Apex, Wake County, N.C. Headquarters: Cherau, S.C., and Sanford, N.C.

Western Pipe Line, Inc., Box 1076, Austin, Tex. *Pacific Gas Transmission Co.* — 468 miles of 36-in. from California-Oregon boundary to Rosalia, Wash., as joint venture with J. P. Neill and Co., Inc. J. C. Oliver is project manager. John Wells is superintendent on 150 miles



The MINIATURIZED-PRECISION WILKINSON Line Locator Model W-3

This radically new, super-powered, transistorized instrument weighs only four pounds and is one-fourth the size of conventional pipe locators.



It is as handy as a flashlight; the maintenance is trivial; the non-leak miniature batteries last ten times longer. Long-life transistors eliminate replacement. Molded glass fibre cases. Transistor ear set. Telescopic handle. Etched circuitry. Contained in carrying case.

WILKINSON PRODUCTS COMPANY
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between Malin and Bend, Ore., and Ervin Simpson is superintendent on 150 miles between Bend and north of Ione, Ore.

Texas Eastern Transmission Corp. — 18-mile, 30-in. from southwest of Wilkesville, Vinton County, Ohio, to near Athens compressor station; and 12-mile, 30-in. from south of Moundsville, W. Va., to Holbrook station near Wind Ridge, Green County, Pa.

Williams Bros. Co., National Bank of Tulsa Bldg., Tulsa, Okla. *National Iranian Oil Co.* — a 516-mile, 8-in. petroleum products line in Iran from Rey, near Tehran, northeast to Meshed.

Bataafse Petroleum Maatschappij, N.V. — a 157-mile, 20-in. in Indonesia. Field office: Balikpapan. Superintendent: J. Childress.

Niederoesterreichische Gasvertriebs, AG (NIOGAS) — 47 miles of 8 through 10-in. in Austria. Headquarters: Herzogenberg. Superintendent: W. Tierney.

Transcontinental Gas Pipe Line Corp. — 76 miles of 36-in. loops in Georgia, South Carolina and North Carolina. Headquarters: Newnan, Ga. Superintendent: Earl Saulsman.

Montana-Dakota Utilities Co. — 106-mile, 12-in. from Minot to Bismarck, N. D.

H. B. Zachry Co., Box 10188, San Antonio 21, Tex. *Dixie Pipe Line Co.* — Demopolis to Griffin, Ga., portion of the 1100-mile, 6, 8, 10 and 12-in. LPG line.

Sterling Construction Co., Box 1186, Sterling Colo. *Service Pipe Line Co.* — 9 miles of 5 and 6-in. gathering lines in the Tisdale field, Johnson County, Wyo.

Bristow-Hyde Engineering Corp., 2040 Tennessee Bldg., Houston 2, Tex. *Mid-America Pipeline Co.* — part of a 107-mile, 6-in. extension from Whiting to Ogden, Iowa, to serve markets in the areas of Mason City, Des Moines, Waterloo and Cedar Rapids.

M-R Construction Co., Box 484, Wichita 1, Kan. *Mid-America Pipeline Co.*—part of a 107-mile, 6-in. extension from Whiting to Ogden, Iowa, to serve markets in the areas of Mason City, Des Moines, Waterloo and Cedar Rapids.

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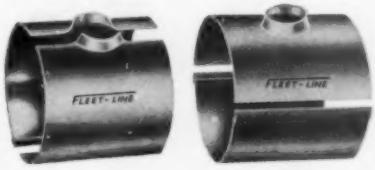

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Pipeline People

Donovan P. Dugan and Edwin L. Ochs, president and secretary-treasurer of Tuscarora Pipe Line Co., have retired from the Standard Oil Co. (N.J.) organization. Dugan joined Tuscarora 30 years ago and became president in 1959. He was loaned to NATO headquarters in Paris in 1957 to supervise the building of a $400,000,000 oil pipeline network and storage facilities in ten NATO countries. Ochs joined the firm 31 years ago and was elected secretary-treasurer and a member of the board of managers in 1954.

Columbia Gas System, Inc., has advanced the following officers: Cecil E. Loomis to vice chairman of the system's parent company, as well as his present position as chief administrative officer; John W. Partridge to president of the parent company and director of the corporation; Fred W. Batten to senior vice president and chief operations officer as well as director of the corporation; Francis H. Crissman to senior vice president and chief financial officer; James S. Phillips to president of the Charleston group companies succeeding Partridge; and Porter Dick to vice president and general manager of the Charleston group companies.

General superintendent of the Calnev Pipe Line Co. system now under construction is I. H. Ricketts, former project engineer for Williams Brothers Co.

John W. Emison, board chairman of The Texas Pipe Line Co., has retired after more than 40 years' service.

Fred S. Jones, Platte Pipe Line Co., has been promoted from superintendent of engineering and communications to chief engineer.

Texas Gas Transmission Corp. has promoted Hoover L. Gibson to design and construction superintendent, William T. Turner, Jr., to director of planning and Paul A. Fedde to director of research. Gibson formerly was compressor engineering superintendent, and Turner and Fedde were senior research engineers.

Robert L. Geiler has joined Columbia Gulf Transmission Co. as training director in the employee relations department. He formerly was senior analyst in the industrial relations department of Shell Chemical Co.

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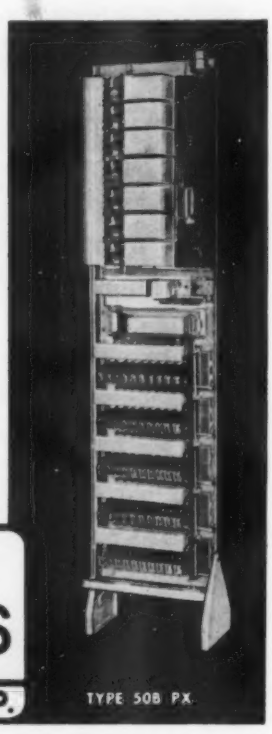


Pipeline Equipment

Prevents Welding Defects

The Hotbox Moisture Control maintains welding electrodes at factory-specified moisture content, providing protection of electrodes from moisture "pick-up" right up to the moment of use. It reduces surface and underbead cracking, hidden porosity, surface splatter and hydrogen embrittlement. Portable and operating from any 115-v a-c or d-c outlet in shop or field, it is available in two sizes for 14 and 18-in. rods. *W Corporation.*

Circle number (81) on reply card

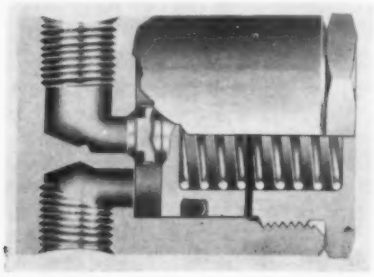
Automatic Fill Valve

For automation of gas engines and compressors, eliminating the need of manually filling the lubricator reservoir, is the new A-30700 automatic fill valve for force feed lubricators. It is made of steel with ball check valve that lifts from its seat by the action of unicellular foam rubber float. It readily fits existing lubricators by top mounting with two screws. It is available also with grounding terminal to shut down gas engine by grounding magnets. *McCord Corp.*

Circle number (82) on reply card

Priority Relief Valve

Complete isolation of any portion of hydraulic or pneumatic systems below a preset point is possible with a new line of priority relief valves. Circle Seal P-458, operating at pressures to 2000 psi, is externally referenced with actuation accomplished by absolute system pressure rather than differential pressure between inlet and outlet. Positive spring pressure opens and closes valve smoothly without sticking or galling. Body of aluminum with chromic anodize finish has ¼-in. female pipe connections. *Circle Seal Products Co., Inc.*



Circle number (83) on reply card

Radio Without Ignition Noise

To suppress ignition noise interference from vehicle electrical systems and to extend operating range of two-way radio systems, Extender models have been added to the transistorized Motrac low-band (25-50 mc) line. Extender operation "turns off" the mobile receiver for the 2-3 microsecond duration of each ignition impulse. Since it takes hundreds of microseconds to transmit a single vowel, quieting the receiver for the impulse duration does not affect the clarity of the message. A 3-position switch on the radio control head enables users to select automatic ignition noise suppression, intermodulation rejection or standard receiver operation. *Motorola Inc.*

Circle number (84) on reply card

Parallel-Wire Tape Punch

A multi-magnet tape punch, designed to receive parallel-wire input from message communications equipment, serves as a "slave" unit in a wide range of data and message communications systems. In data collection systems, electro-mechanically operated Model 28 LARP records information gathered from many sources into one "combination" master tape which can be used in communications systems, thus simplifying data relaying. It provides programmed storage in fully perforated tape. Operating at 20 characters per sec, it is available for 5, 6, 7 or 8 level operation and removes the problem of tape preparation from system planning. *Teletype Corp.*

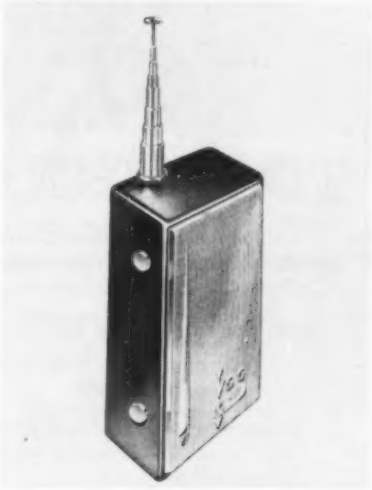
Circle number (85) on reply card

Deliver Oil-Free, 100-Lb Air

C-100 two-stage Spiraxial compressor units deliver up to 3000 cfm oil-free air at 100 psig. The two compressors in the machine are driven in tandem by a standard 3600 rpm motor or turbine. Two intermeshing screw-type rotors provide axial-flow compression in each stage. There are no vanes, valves, pistons or rings to wear or present maintenance problems. The 900-cfm model is less than 7 ft long (less driver) and 3½ ft wide (including cooler) and weighs 4000 lb. C-100 Spiraxial compressors are available in seven sizes from 900 cfm to 3000 cfm. *Roots-Connersville Blower, Div. of Dresser Industries, Inc.*

Circle number (86) on reply card

Powerful Walkie-Talkie



Powerful transmission and clear reception of the ICC Herald Walkie-Talkie are attributed to new features in fundamental design and construction. With nine transistors plus one diode and one thermistor, it has an unobstructed range of up to 10 miles. Telescopic whip antenna extends to 52 in. Maximum power is 100 mw for the 27 mc Citizens Band. Transmitter and superheterodyne

receiver are fully crystal controlled and all circuitry is printed. Entire unit weighs 15 oz, less batteries. *International Communications Corp.*

Circle number (88) on reply card

Rectifier Has Unique Meter

"Cyclops Eye" meter scale which reads in amps or volts is now standard on all Good-All cathodic protection rectifiers. Designed to speed checking time and increase accuracy, the switching circuit single-switch operation provides lightning damage protection and is said to cut replacement costs in half. It is color-keyed to the switch with red scale reading amps and lower, blue scale reading volts. *Good-All Electric Mfg. Co.*

Circle number (89) on reply card

Portable Boring Machine

A compact road boring machine is offered for small diameter road boring jobs. A 7½-hp gasoline engine with kick starter furnishes power for the entire operation. The machine is easily transported in a pick-up truck since it is only 76 in. long, 39 in. high and 20 in. wide and weighs 595 lb. It has bored holes up to 75 ft with almost pin-point accuracy, according to the manufacturer. Fingertip hydraulic power does the heavy work. Only 12 ft of open ditch is required to operate the machine, which can be positioned in bell hole ready for boring within a few minutes. *Crose-Perrault Equipment Corp.*

Circle number (90) on reply card

TV Inspects 4-48-In. Lines

A mass-produced complete television system for inspection of oil and gas lines, tanks, conduits, etc., is now on the market. This water-tight system is complete with enclosed lighting system, 500 or 1100 ft of cable and generator. It is capable of being pulled through pipelines as small as 4-in. in diam and as large as 48-in. *Inspectoline Inc.*

Circle number (91) on reply card

Literature

Topazometer Introduced

Introduction of the Topazometer, which may be used as a low pressure deadweight gage or a high range differential pressure manometer, is made in a 4-page bulletin. *ToPaz, Inc.*

Circle number (92) on reply card

Poxyglas Tank Chart

A handy "Poxyglas Corrosion Resistant Chart" for use as a guide in the applications of Poxyglas tanks for corrosive service highlights a new 6-pager. Features of the glass-resin material and the manufacturing method are discussed. *Black, Sivalls & Bryson, Inc.*

Circle number (93) on reply card

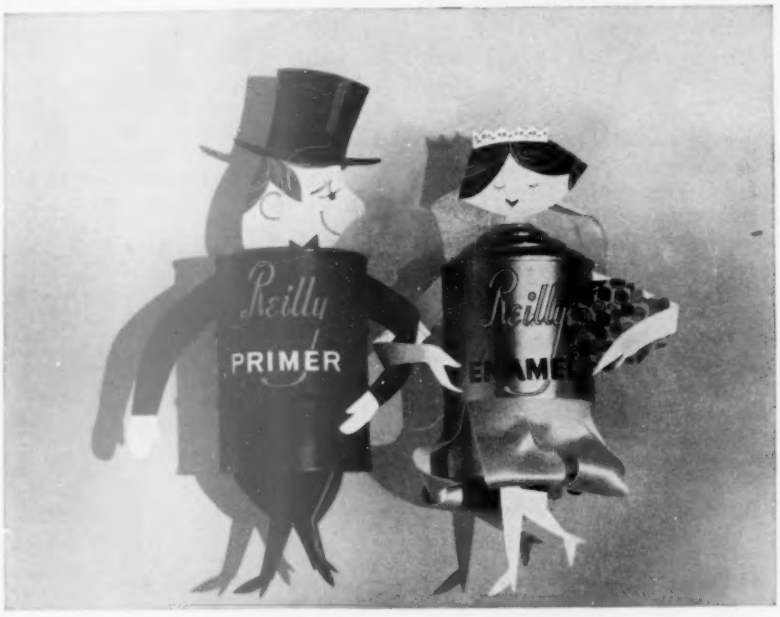
Discusses Plans For LACT

System automation designed to meet specific LACT problems is the subject of illustrated literature. The system described is designed in units being added according to the master plan until entire automation is achieved. *The Ralph M. Parsons Co.*

Circle number (94) on reply card

Gas Installation Handbook

How to install plastic pipe for low pressure gas gathering service is told in the 28-page "Gas Installation Handbook." It contains: data on fittings for plastic pipe; American Gas Association recommendations for plastic pipe installations; data on operating pressures and temper-



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Reilly Coal Tar Enamels and related primers, used together, provide the corrosion protection needed by underground metal structures. The Reilly hot enamel system is:

electrically insulated	oxidationproof
waterproof	stressproof
oilproof	tough and strong
bacteriaproof	permanently bonded

In addition, Reilly coating systems offer ultimate longevity because they inherit the chemical inertness and stability of coal tar, from which they are made.

Specify Reilly hot-applied coal tar enamels and related primers for oil, gas and water pipelines.

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Reilly 230 AWWA Enamel	Reilly 230 X-10 Primer	
Reilly Hot Service Enamel	Reilly 230 X-10 Primer	

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atures; physical specifications; and explanation of an emergency control technique for repairing plastic lines carrying gas. *Naugatuck Chemical Div., United States Rubber Co.*

Circle number (95) on reply card

Pipe Chart For Desk Or Wall

Pipe dimension chart for desk or wall mounting shows outside diameter and wall thickness for all sizes of pipe from ½ through 42 in. It includes information from ASA Standard B36.10, showing IPS and schedule numbers and their relationship, and includes latest wall thicknesses added in the 1959 revision. *Midwest Piping Div., Crane Co.*

Circle number (96) on reply card

Practical Welding Data

"Welding Pressure Pipe Lines and Piping Systems" contains practical information on hand welding and automatic submerged arc welding and charts on pounds of electrode consumed per joint for various diameter pipe using either method. *Lincoln Electric Co.*

Circle number (97) on reply card

Information On Couplings

Flexible couplings for steel or cast iron pipe highlight a new 14-pager. Straight, transition, reducer, tee, and repair from ½ to 24-in. are described. Standard heavy-duty steel, long sleeve, and insulating couplings are included. *R. H. Baker and Co., Inc.*

Circle number (98) on reply card

The Story Of Estor G

This is a colorful, illustrated booklet on a specially developed lubricant for gas engines. It tells what it is, why it was developed and what it has done in field tests. *Humble Oil & Refining Co.*

Circle number (99) on reply card

Loader Reference Book

A good application reference is the new catalog on 4-wheel-drive loaders. In 16 illustrated pages, it lists specifications on each of three models. *J. I. Case Co.*

Circle number (100) on reply card

TV Monitors

Intra-Tel industrial television monitors, including 14, 17 and 21-in. screen sizes in cabinet and rack-mount models, highlight a new 4-pager. *General Electric Communication Products Dept.*

Circle number (101) on reply card

Gas Engine Performance

Two-cycle gas engines, with particular emphasis on their performance characteristics in variable-speed, variable-load applications, are featured in a new bulletin. *Clark Bros. Co., One of the Dresser Industries, Inc.*

Circle number (102) on reply card

Centrifugal Compressor Data

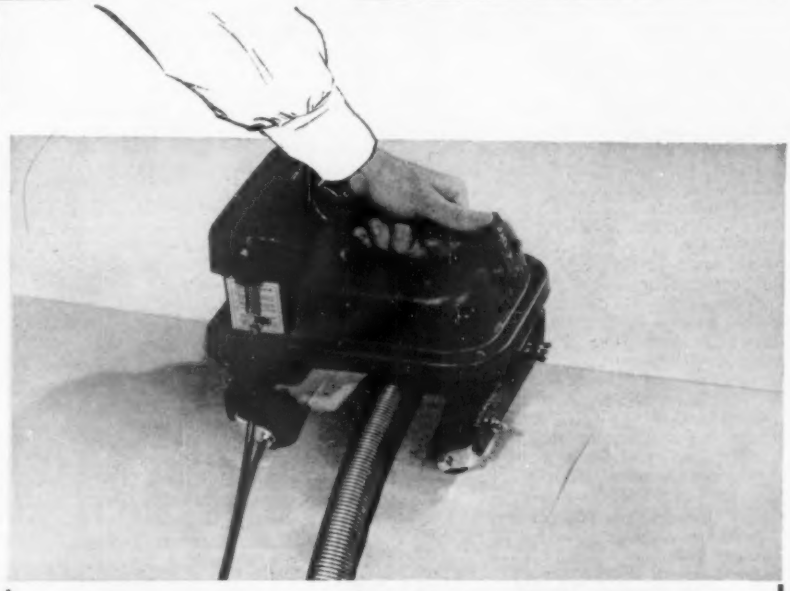
Air applications requiring up to 15,000 cu ft per min inlet volume at 100-125 psig are met by a six-stage, single casing, water-cooled centrifugal compressor. A new bulletin includes approximate outline dimensions of the Type VC compressor and a typical performance curve. *Allis-Chalmers Mfg. Co.*

Circle number (103) on reply card

Q. & A. About Valving

Questions and answers about valving in modern reciprocating compressors appear in a new 44-page booklet. With cartoons and cut-away drawings, it details the demands made on valves and their function in a compressor. *Ingersoll-Rand Co.*

Circle number (104) on reply card



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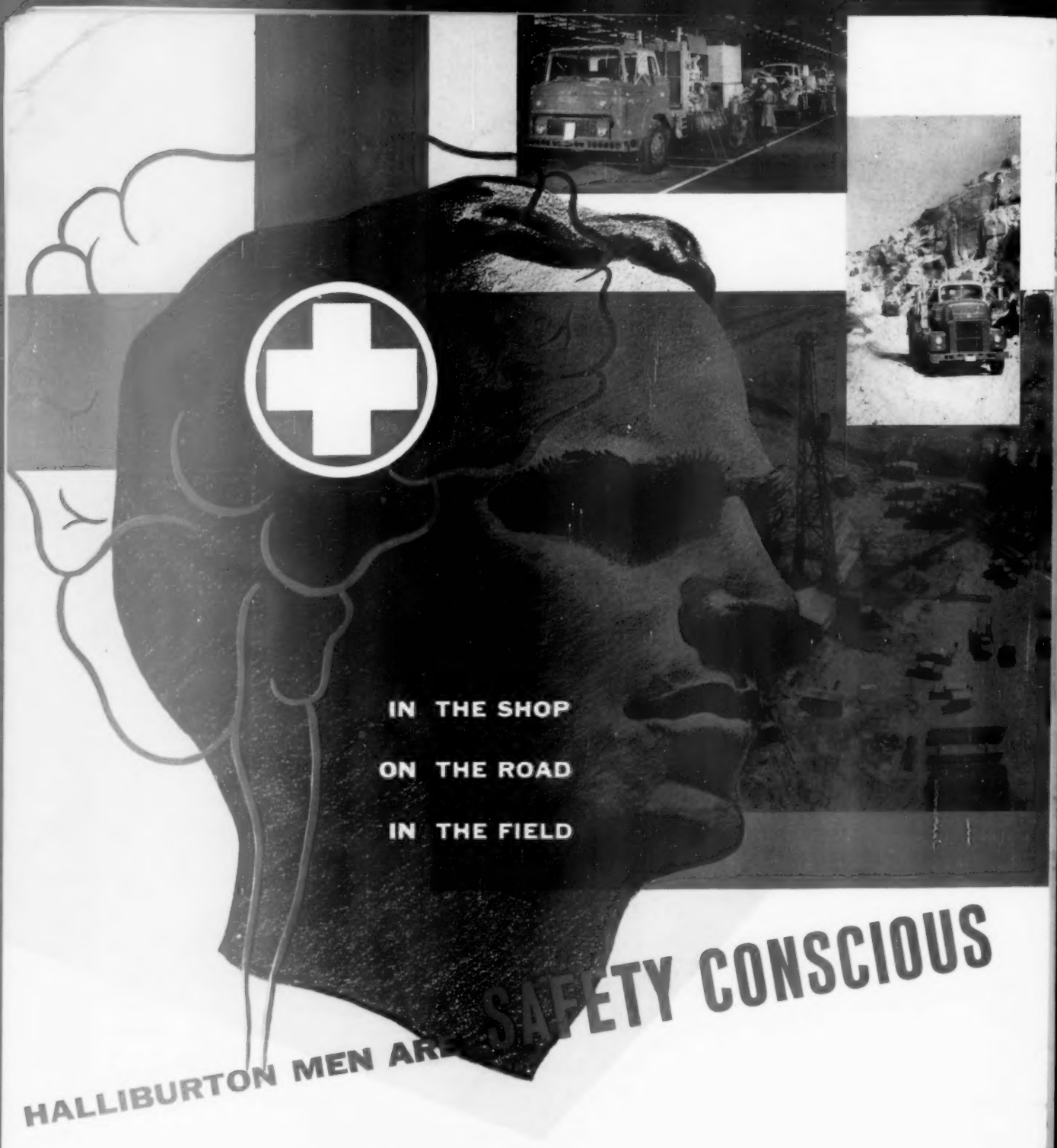
P. O. BOX 1407 HOUSTON 1, TEXAS
DRESSER INDUSTRIES, INC.
OIL-GAS-CHEMICAL-ELECTRONIC-INDUSTRIAL



HALLIBURTON MEN ARE SAFETY CONSCIOUS

"Beware" — the precautionary word that signals danger — is better expressed at Halliburton as "BE AWARE." Halliburton people are aware of the benefits to themselves and their customers of being Safety Conscious. Safety signs remind them, safe operations reward them, and safety awards recognize their safety-conscious endeavors.

A safe company is a good company to deal with . . . Halliburton is both.

Halliburton COMPANY
DUNCAN, OKLAHOMA